2-23-2021

Participation in Open Up Resources by Gender and Family Income Level on Mathematics Achievement of Grades 7 and 8 Students

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PARTICIPATION IN OPEN UP RESOURCES BY GENDER AND FAMILY INCOME LEVEL ON MATHEMATICS ACHIEVEMENT OF GRADES 7 AND 8 STUDENTS

by

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Dissertation

Submitted to the Faculty of

Harding University

Cannon-Clary College of Education

in Partial Fulfillment of the Requirements for

the Degree of

Doctor of Education

in

Educational Leadership

May 2021

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Dissertation Advisor	02.23.21 Date
Dissertation Reader	2-23-21 Date
Dissertation Reader	02.23.21 Date
Dean of the Cannon-Clary College of Education	2-23-21 Date
Provost	2/23/21 Date

ACKNOWLEDGMENTS

For the entire law is fulfilled in keeping this one command: "Love your neighbor as yourself." Galatians 5:13

The process of working on this dissertation has provided an opportunity to grow as a person, a servant of God, and an educator. This growth has come, in large part, due to the encouragement and love I have received from others. My parents, Thomas and Reba "Juanez" Brister, provided an example of what it means to serve and care for others, taught me the value of hard work, and supported me throughout this process. My wife, Amelia, provided support, prayers, and encouragement. She spent many hours editing drafts of my work.

All of the professors at Harding University have been incredibly supportive and encouraging throughout my work. Specifically, my advisor, Dr. Akpanudo, mentored me with great patience and understanding. Dr. Brooks and Dr. Mathews served as readers on my committee. I consider these professors both mentors and friends.

Others such as Wil Perkins, Tim Davis, Terry Kernodle, Frank Pitts, my work family at Wilbur Mills Cooperative, and many others I have not mentioned by name have provided listening ears, prayers, encouragement, love, and laughter.

I also want to thank God for His love towards me and am grateful that He has allowed this work to be a part of my life. I pray that this work will honor God, and I thank Him for His continual work in my life.

ABSTRACT

by
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Harding University
May 2021

Title: Participation in Open Up Resources by Gender and Family-Income Level on Mathematics Achievement of Grades 7 and 8 Students. (Under the direction of Dr. Usen Akpanudo)

The purpose of this dissertation was to determine the effects by gender and by family-income level between students using Open Up Resources (OUR) curriculum (a Problem-Based Learning [PBL] curriculum) versus traditional curriculum on mathematics achievement of Grades 7 and 8 students. A stratified random sample of 320 students from four Central and Southeast Arkansas schools (*n* = 160 for Grades 7 and 8, respectively) was drawn for this study. Data analysis involved the use of 2 x 2 factorial ANOVAs. The key findings of the study were that the mathematics achievement of Grade 8 students using OUR was significantly higher than the scores of those using traditional mathematics curricula. The scores of Grade 7 students using both curriculum types were similar. Seventh-grade females had higher mathematics achievement than males. Students from low family-income levels had lower mathematics achievement in both grades than those from higher family-income levels. Based on these findings, PBL curricula such as OUR are recommended as a strategy for closing gaps in mathematics achievement.

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CHAPTER I

INTRODUCTION

Transitioning mathematics instruction from classroom instruction to application in novel situations has become a challenge for graduates in the United States. Many adults in the United States struggle with mathematics after graduating from high school. In 2017, only 34.4% (compared to a 42.2% international average) of adults in the United States reached proficiency Level 3 or above (Levels 3, 4, or 5) on the Organization for Economic Cooperation and Development (OECD) Survey of Adult Skills, a part of the *Programme for the International Assessment of Adult Competencies* (OECD, 2019). A proficiency Level 3 on the *Programme for the International Assessment of Adult Competencies* survey represents the ability to perform tasks that "…require the application of number sense and spatial sense; recognizing and working with mathematical relationships, patterns, and proportions expressed in verbal or numerical form; and interpreting data and statistics in texts, tables, and graphs" (p. 13). Adults in the United States were unable to demonstrate the ability to apply mathematical knowledge to the items on the *Programme for the International Assessment of Adult Competencies* survey. Results of the 2012 *Programme for the International Assessment of Adult Competencies* survey were similar to the 2017 results, and members of OECD (2019) noted that even though the education level is higher in the United States than in most participating countries, United States students demonstrated a weaker application of basic numeracy skills. The problem seems to persist over time. Adults in the United Stated have not compared favorably to international students in measures of the application of numeracy skills.

Students in the United States have also failed to demonstrate reasoning and application of knowledge gained in the mathematics classroom. This problem was illustrated by Kaplinsky (2013) when he interviewed 32 eighth-grade students with the question, “There are 125 sheep and five dogs in a flock. How old is the shepherd?” (para. 1). Seventy-five percent of the students Kaplinsky interviewed gave a numerical answer to the question rather than stating that the question made no sense. The students interviewed did not express reasoning about the problem presented and did not appear to connect common sense knowledge to mathematics. The National Assessment of Educational Progress (NAEP, 2019) Mathematics Assessment measures the United States fourth- and eighth-grade students' knowledge, skills, and ability to apply knowledge in problem-solving situations. According to the Institute of Education Sciences National Center for Education Statistics (2019), only 33% of eighth-grade students nationally and 27% of students in Arkansas scored at the NAEP proficient level or above on the 2019 mathematics assessment. Students taking the assessment appeared unable to apply knowledge learned to the NAEP Mathematics Assessment. Both anecdotal data and assessment results indicate that many American students cannot demonstrate the ability to reason mathematically or apply mathematical knowledge proficiently.

Educators’ use of quality curricular materials can help develop student mathematical reasoning and apply mathematical knowledge. Drinan (1997) asserted that curricula could influence students’ motivation for learning, decision-making ability, acquisition of knowledge, awareness of the complexity of issues, and capacity for self-directed learning. A well-written curriculum might address each of these elements. Bergqvist and Bergqvist (2017) asserted that curricula designed for traditional mathematics focused primarily on content and ability to apply procedures, and more contemporary, problem-based materials focused more centrally on problem-solving, reasoning, representing, connecting, and communicating. The choice of mathematics curriculum resources may affect the way students experience mathematics. Educators' curriculum choices may influence students' abilities to reason mathematically and to apply mathematical knowledge.

The use of problem-based learning (PBL), based on constructivist learning theory, might encourage students' mathematical reasoning and the ability to apply mathematical knowledge. Dewey (1938) proposed that experience is the optimal stimulus for learning, and educators should structure the learning environment to encourage learning to occur. Students learning in an experiential environment are active participants in learning. Students experientially learning would apply the knowledge they have in a way that activates new learning. PBL enables understanding in this way. Barrows (1996) claimed that PBL is a method of instruction emphasizing reasoning and problem-solving, allowing for improved utilization of knowledge in real-world contexts. Students' experiencing this method of teaching would regularly apply mathematical knowledge to solving problems. Hiebert et al. (1996), while discussing PBL, called for the *problematization* of mathematics, "…allowing students to wonder why things are, to inquire, to search for solutions, and to resolve incongruities" (p. 12) as a way to increase students' mathematical understanding and ability to apply mathematics. The problematization of mathematics supports students' experience of both purely mathematical and real-world problems. Students in PBL environments experience learning by becoming activated in the mathematical learning process through using problems.

Open educational resources, including the problem-based Open Up Resources (OUR) Mathematics curriculum, are now available to educators. According to the OECD (2007), open educational resources are digitized materials offered freely and openly for educators, students, and self-learners to use and reuse for teaching, learning, and research. Open resources are a low-cost or free alternative to commercially available materials. OUR Mathematics curriculum is a problem-based curriculum for students in Grades 6-8 addressing the practice and content standards outlined in the *Common Core State Standards for Mathematics*. The curriculum is freely available online (Illustrative Mathematics, 2019). Since the OUR Mathematics Curriculum is freely available to educators, many school educators may consider using the OUR curriculum. Open Educational Recourses, including OUR, represent a free or low-cost option for educators seeking curricular resources.

Educators considering curricular resources for mathematics have several options, and educators may find this study useful when making mathematics curricular decisions. Slavin, Lake, and Groff (2008) categorized three types of mathematics curricular materials: (a) textbooks that emphasize problem-solving, alternative solutions, and conceptual understanding using innovative strategies; (b) textbooks with a more traditional balance between algorithms, concepts, and problem-solving; and (c) textbooks that emphasize a step-by-step approach to mathematics. Educators may choose from a variety of mathematics curricular materials. In this study, PBL resources, specifically OUR, will be investigated to provide educators with information that may be used when considering mathematics curricula resources.

Statement of the Problem

The purposes of this study were four-fold. First, the purpose of this study is to determine the effects by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Second, the purpose of this study is to determine the effects by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools.

Third, the purpose of this study is to determine the effects by family-income level (as measured by school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Fourth, the purpose of this study is to determine the effects by family-income level (as measured by school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools.

Background

Theoretical Framework: Constructivism

Proponents of constructivism claim that learning occurs as learners construct knowledge based upon their experiences. Piaget (1975) theorized that logic does not arise through language but coordination of actions. Piaget recommended that instructors begin with a qualitative investigation and then follow with more formal representations at a time that will accompany students' development of logic structures. In Piaget's model, students construct logical structures as they act upon problems. Vygotsky (2017) built on the theory of constructivism by hypothesizing that learning occurs in the *zone of proximate development,* which represents the gap between what a student can do with the help of an adult and what can be completed independently. According to Vygotsky, learning occurs when teaching focuses on applying prior knowledge to tasks that fall within the zone of proximate development, and students develop logical structures which they can use to solve a variety of other problems. As suggested by Vygotsky, teaching would require that teachers present students with problems before they can perform them independently. According to constructivist theory, students develop logical structures as they experience challenging problems (see Figure 1).

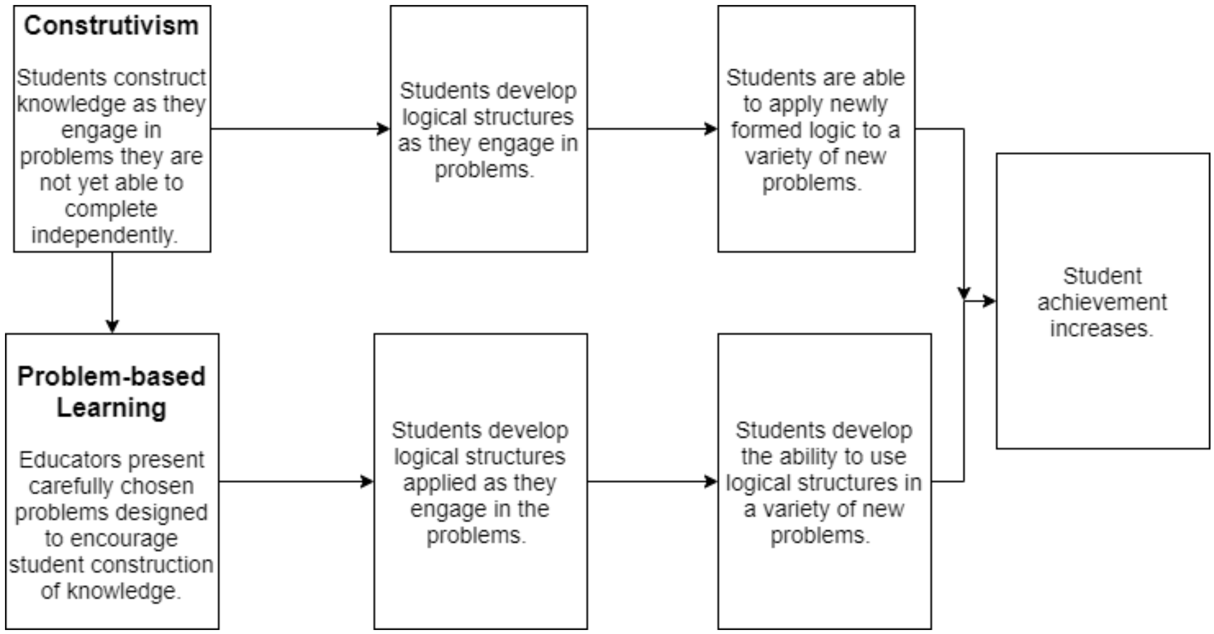

Figure 1: Progression of constructivism and problem-based learning toward student achievement.

Educators employing constructivist theory would expect students to construct logical structures as they engage in presented problems. Beard (2018) described constructivism as a system in which educators attempt to create concrete, educative experiences leading the learner to new observations and understandings. Constructivism involves the use of carefully designed experiences to promote students' construction of knowledge. Cooper (1993) equated learning in constructivism to problem-solving. Students' in a constructivist classroom setting apply the knowledge they have to solve problems. Constructivists create experiences designed to prompt learners to build on their existing knowledge to construct new knowledge.

Problem-Based Learning

Instructors of medical students developed PBL to engage medical students in the experience of learning, and the practice expanded to diverse fields of knowledge.

Barrows (1996) reiterated that the creation of PBL was a response to students' claims that knowledge gained in medical school was irrelevant in the practice of medicine. The goals of PBL include developing problem-solving skills, supporting self-directed learning as a lifetime habit, promoting teamwork, and acquiring an integrated body of knowledge from many different subject areas or disciplines (Barrows, 2002). The goals of PBL are focused on the learners' experiences rather than on the educator. PBL rapidly spread to other fields such as mechanical engineering, social work, optometry, architecture, nursing, legal training, business, and industry (Boud & Feletti, 1997). Each of the fields of study required different problems, but the goals remained applicable. PBL was developed in the medical field and quickly expanded to other disciplines.

PBL represents an application of the theory of constructivism since problem-solving has remained central to PBL implementation. Barrows (1986) noted that PBL was modified for particular applications in various fields of knowledge. Still, the defining attribute of PBL, compared to other teaching methods, is the use of problem-solving as the stimulus for learning. Barrows' viewpoint aligned with Cooper's (1993) description of learning in constructivism as problem-solving. Barrows explained that problems might include posed questions, unexplained phenomena, or problems involving health or community in the instructional sequence. Although strategies may vary across different disciplines, the use of problems characterized all applications of PBL. Boud and Feletti (1997) also asserted that problems are a part of PBL implementation but warned that PBL requires a change in instruction rather than merely adding problem-solving exercises to traditional curricula. The student-centered goals of PBL require that facilitators engage students in problem-solving rather than only including problems in exercise sets. PBL's use of problems to motivate students' learning is an application of constructivist theory.

Problem-Based Learning in Mathematics

The use of a problem-based approach in mathematics may encourage greater mathematical understanding in students. Some have described a problem-based approach in mathematics as one that makes use of real-world problems, integrates learning of understanding with the learning of skills, involves student sharing and discovery, emphasizes both process and product, and may use both student-created and teacher-created problems (Hiebert et al., 1996, Jensen, 2015). The integration of these characteristics promotes learning that goes beyond memorization and applications of procedures. Schoenfeld (1988) asserted that students learning through only memorization and practice of mathematical procedures exhibited a fragmented understanding of mathematics and exhibited many mathematical misconceptions about the inability to make connections between different procedures and ideas. Schoenfeld emphasized that problem-solving tasks that require higher-order thinking should be used regularly in the mathematics classroom. The focus on problems in PBL may lead to greater student understanding and diminish misunderstandings associated with an overemphasis on procedures. Students' understanding and application of mathematics may improve with the use of problem-based strategies.

However, researchers have reached conflicting conclusions regarding the effectiveness of PBL practices. While some researchers have reported positive effects on student achievement measures with the use of problem-based strategies (Rosli, Capraro, & Capraro, 2014; Şad, Kiş, & Demir, 2017; Trinter, Moon, & Brighton, 2015), researchers conducting other studies noted no effect on students achievement with the use of PBL (Cai, Wang, Moyer, Wang, & Nie, 2011; Maree & Molepo, 2005). Although the results of some studies would support the claim that PBL is the preferred instructional method for increasing student achievement, other study results have indicated no significant difference in instructional methods. Boaler (1998), Ridlon (2009), and Rosli et al. (2014) have described increased student problem-solving skills and more positive student perceptions of mathematics with PBL. Even with mixed results of studies that compared PBL with instructional methods for effect on student achievement, results of studies that indicated increased problem-solving skills and attitudes toward mathematics might prompt educators to consider the use of PBL.

Gender and Mathematics Achievement

Differences in mathematics instruction could affect the achievement of males and females in mathematics. Fennema and Hart (1994) performed a meta-analysis of previous research on gender and mathematics achievement and noted a gender gap in mathematics, with males scoring higher on achievement measures than females. More recently, Voyer and Voyer (2014) and Robinson and Lubienski (2011) reported achievement gaps favoring males over females on mathematics achievement. Mathematics achievement differences by gender have long been a topic of study. After conducting a large-scale analysis of gender and mathematics achievement using international data the Trends in International Mathematics and Science Study and the Programme for International Student Assessment, Else-Quest, Hyde, and Linn (2010) revealed much variability existed by nation and proposed that other factors such as culture, instructional practices, or family-income level may have affected achievement by gender. Determining if the factors proposed by Else-Quest et al. (2010) affect mathematics achievement by gender would require further study. Differences in mathematics achievement by gender may relate to the type of instruction students receive.

Educators' choices of problem-based instruction or traditional instruction may affect mathematics achievement by gender. Lindberg, Hyde, Petersen, and Linn (2010), concluded that males performed better than females on multiple-choice items, but females outperformed males on open-ended items. Educators using PBL advocate the use of more open-ended items in mathematics instruction. Boaler and Staples (2008) observed no achievement difference in males and females implementing a problem-based approach, and a gender difference remained at similar schools using a traditional approach. The type of instruction could influence gender differences in the mastery of mathematics concepts. Problem-based instruction and traditional instruction may affect the mathematics achievement of males and females.

Family-Income Level and Mathematics Achievement

Observed achievement differences between student groups, based on family-income levels, may be related to differences in learning opportunities. According to meta-analysis results reported on Corwin Visible Learning Meta X (2019), a site that regularly adds and compiles meta-analysis on various educational topics, the level of household income significantly affects student achievement. The significance of the effect by the level of household income should not be interpreted as an inherent difference in students having these backgrounds but as an incentive to look deeper into the effect's causes. Gustafsson, Nilsen, and Hansen (2018) identified family income as a powerful influence on student achievement and noted that students living in poverty (identified by qualification for free or reduced-cost lunches) were more likely to receive poor quality instruction than those not qualifying for free or reduced-cost school lunches. If a difference in achievement by household income levels (school lunch status) exists, differences in the quality of instruction could cause the gap to widen. Payne (1996) proposed that achievement differences for students from families with low-income backgrounds are not due to differences in ability but are due to differences in background knowledge. Payne asserted that changes in teaching practice could help students from backgrounds of poverty achieve at higher levels. The use of quality instructional practices in all classes may provide students, including those from low family-income backgrounds, the opportunity to engage in rigorous mathematics. Differences in opportunities of students, based on a family's income status (whether deliberate or accidental), to engage in rigorous mathematics may explain achievement gaps between students qualifying for free or reduced lunch and those who do not qualify.

Learning in a problem-based environment could influence the attitude and achievement of students with different family income backgrounds. Gibbs and Hunter (2018) noticed that students from both high- and low-socioeconomic backgrounds perceived themselves as doers and users of mathematics when problems focused on exploring and understanding mathematical relationships rather than solely on procedures and correct answers. Students' awareness of being able to do mathematics and the usefulness of mathematics might positively impact mathematics achievement. Hwang, Choi, Bae, and Shin (2018) indicated that the mathematics achievement gap by level of family income narrowed when student-centered, rather than traditional instruction, was employed in teaching mathematics. Holmes and Hwang (2016) recorded no differences in the effects of PBL versus traditional instruction on student achievement, even if poverty was a factor. Conflicting results of studies of how the level of family income affects mathematics achievement prohibit a confident conclusion. Results reported by researchers investigating the effects of problem-centered instruction on students from differing family income backgrounds are mixed and could be a reason to investigate further the relationship between PBL and student achievement by family income status.

Hypotheses

The following hypotheses were generated:

1. No significant difference will exist by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools.
2. No significant difference will exist by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools.
3. No significant difference will exist by family-income level (school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools.

4. No significant difference will exist by family-income level (school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics test for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools.

Description of Terms

ACT Aspire. The ACT Aspire (2016) is a "vertically articulated system of summative, interim, and classroom assessments" designed to measure student achievement in English, mathematics, reading, science, and writing for Grades 3-8 and early high school (ACT Aspire, 2016, para. 2). For this study, ACT Aspire will be used to refer to the summative assessment, which is administered to Arkansas public school students in Grades 3-10 unless they qualify for an alternate assessment (Arkansas Department of Education, 2014). ACT Aspire was used in this study as the operational definition of mathematics achievement.

Conceptual knowledge (understanding). According to the National Council of Teachers of Mathematics (2014), conceptual understanding is the ability to explain the mathematical basis for procedures used, demonstrate flexible use of strategies, and determine whether strategies generalize to a broader set of problems.

Department of Elementary and Secondary Education (DESE). As part of Governor Asa Hutchison's reorganization in 2019, the Arkansas Department of Education became the Department of Elementary and Secondary Education (Brantley, 2019). The Department of Elementary and Secondary Education refers to the entity formerly called the Arkansas Department of Education (ADE). The Department of Elementary and Secondary Education is now a department of ADE, which includes other departments.

Family-Income Level. The Arkansas Department of Education (2010) classified students who qualify for free or reduced lunches in the National School Lunch Program as low income and eligible for supplemental education services. Students reported as qualifying for free or reduced lunch in the National School Lunch Program are reported as economically disadvantaged on the Arkansas reports of achievement measures. School lunch status will be used in this study as the operational definition for family-income level. Family-income level is often referred to *as socioeconomic status*, SES (Pomeroy, 2016; Sirin, 2005; White & Reynolds, 1993).

Open Up Resources (OUR) Mathematics Curriculum. OUR mathematics curriculum is an open-source, standards-aligned (aligned to the Common Core State Standards for Mathematics) core curriculum for Grades 6-8 funded by OUR and authored by Illustrative Mathematics (OUR, 2019). Members of Illustrative Mathematics (2019) described the curriculum as a problem-based core curriculum designed to address content and practice standards and foster learning by engaging students in learning by doing mathematics, solving mathematical and real-world problems, and constructing arguments using precise language.

Mathematical problem. According to Hiebert et al. (1996), a mathematical problem is a mathematical task that encourages students to "…wonder why things are, to inquire, to search for solutions, and to resolve incongruities" (p. 12), as opposed to a mathematical exercise involves only direct application of previously-learned procedures to obtain an answer.

Problem-based curriculum. Members at Illustrative Mathematics (2019) defined a problem-based curriculum as a curriculum in which students work on carefully crafted and sequenced mathematics problems during most of the instructional time.

Problem-based learning (PBL). Boud and Feletti (1997) defined PBL as constructing and teaching courses using problems as the stimulus and focus of student activity.

Procedural knowledge (fluency). Hiebert and Lafevre(1986) defined procedural knowledge as knowledge of the symbol representation system of mathematics and algorithms (rules) for completing mathematical problems.

Traditional curriculum. Bergqvist and Bergqvist (2017) defined traditional mathematics curriculum as a mathematics curriculum focused primarily on content and applying procedures. In this study, traditional curriculum will refer to Big Ideas Math curriculum, a commercially available text, or Engage NY, a curriculum available as an Open Educational Recourse.

Significance

Research Gaps

This study provided quantitative data on the effect of using PBL, specifically the OUR Mathematics Curriculum, to assist educators in making decisions about curriculum. Increasing numbers of schools and districts across the United States are using OUR curriculum (Business Wire, 2018). OUR is a problem-based mathematics curriculum. Several researchers have investigated the effect of problem-based curricula and materials on student achievement (Cai et al., 2011; Kul, Çelik, & Aksu, 2018; Şad et al., 2017), but studies explicitly focused on OUR are needed. Some teachers, such as Powers (2019), have shared anecdotal data, and the results seem promising. This study provided quantitative results on the effects of OUR on student achievement in mathematics. The results of this study will contribute to the knowledge-base to assist schools and districts considering the choices of curriculum materials for mathematics in Arkansas and other states.

Possible Implications for Practice

The results of this study could provide schools and districts in Arkansas specific data on the effects of the use of OUR mathematics curriculum on student achievement. Districts and school leaders could use these data to inform decisions about adopting curricular materials for mathematics. State educational agencies could use the results of this study when choosing curricular mathematics materials for use in professional development or when recommending materials to districts. Universities could use the findings in this study to inform faculty, staff, and future educators about available mathematics curricular materials. If the free OUR Mathematics Curriculum materials are as effective as or more effective than higher-cost materials, school administrators may want to consider the fee materials. The results of this study could be used as background knowledge contributing to further research on OUR or other problem-based curricular materials, whether open-source or commercial.

Process to Accomplish

Design

A quantitative, causal-comparative strategy was used in this study. For Hypotheses 1 through 4, the researcher used four 2 x 2 factorial between-groups designs. The independent variables for Hypotheses 1 and 2 were the type of mathematics curriculum (OUR versus traditional) and gender (male versus female). The independent variables for Hypotheses 3 and 4 were the type of mathematics curriculum (OUR versus traditional) and school lunch status (free or reduced lunch versus no free or reduced lunch). The dependent variable for Hypotheses 1 through 4 was mathematics achievement measured by ACT Aspire mathematics test scores.

Sample

This study's sample included scores from seventh- and eighth-grade students at two rural schools in Central Arkansas and two rural schools in Southeast Arkansas. The two schools in Central Arkansas, one using OUR and one using Big Ideas Math, were similar in demographics. The OUR school had a student population that consisted of Caucasian (92%) and Hispanic (8%). The comparison school had a racial demographic of Caucasian (88%), Hispanic (8%), American Indian/Alaskan Native (2%), and Two or more (3%). Family-income level was determined by lunch status, with 37% of the OUR school's population on free or reduced lunches and 34% of the comparison school's students receiving free or reduced-cost lunches. The two schools were also similar in school demographics regarding grade configuration (i.e., seventh grade included in elementary and eighth grade included in high school), district size (OUR = 764 and comparison = 842), and the average teacher tenure at the present school (OUR = 12.56 years and comparison = 11.78 years). A difference was indicated in the student-teacher ratio (OUR = 5:1 and comparison = 8:1).

There were some demographic differences between the two Southeast Arkansas schools, one using OUR and one using Engage NY, from which sample student data were drawn for this study. For instance, the OUR school had a student population that consisted of Caucasian (78%), African American (14%), Hispanic (5%), and Two or more (2%). The comparison school had Caucasian (83%), African American (10%), and Hispanic (5%), and Two or more (2%). Family-income level was determined by lunch status, with 62% of the OUR school's population on free or reduced lunches and 1% of the comparison school's students. Other demographics for the two schools included grade configuration (a Grades 6-7 middle school building for the OUR school and a Grades 7-12 high school building for the comparison school), district size (OUR = 1,219 and comparison = 634), the average teacher tenure (OUR = 12.1 years and comparison = 8.2 years), and student-teacher ratio (OUR = 11:1 and comparison = 7:1). The scores of students from each of the two OUR schools were stratified by grade level, gender, and family-income level for the data analysis. Students' scores from the two schools using a traditional mathematics curriculum were also stratified by grade level, gender, and family-income level.

Instrumentation

In the spring, educators in all four schools administered the ACT Aspire mathematics subtest to all the students as part of the ACT Aspire Summative Assessment to measure achievement. ACT (2019) noted that the mathematics test measures topics including the number system, expressions and equations, ratios and proportional reasoning (Grade 7), functions (Grade 8), geometry, and statistics and probability. The test also includes lasting topics from previous grades: numbers and operation in base 10, numbers and operations-fractions, operations and algebraic thinking, and measurement and data. Item types on the subtest include selected-response, constructed-response, and technology-enhanced. Each correct selected-response and technology-enhanced item has a score of 1 point with no points deducted for incorrect responses. Trained raters score constructed-response items according to a predetermined rubric. The mathematics scale score ranges from 400-453 in seventh grade and 400-456 in eighth grade, with 400 being a low score (ACT, 2019). ACT Aspire test items are aligned to predetermined benchmarks and undergo rigorous internal reviews and external audits to ensure validity. According to ACT (2019), Cronbach's alpha was used to determine an internal reliability coefficient range for the mathematics test in each grade: seventh grade (.86 - .87) and eighth grade (.87 - .88).

Data Analysis

Two by two factorial between-groups analyses of variance (ANOVAs) were conducted to address Hypothesis 1 and 2 using the type of mathematics curriculum (OUR versus traditional) and gender as the independent variables. Two by two factorial between-groups ANOVAs were conducted to address Hypotheses 3 and 4 using the type of mathematics curriculum (OUR versus traditional) and school lunch status as the independent variables. The dependent variable for all four hypotheses was student mathematics achievement, as measured by the ACT Aspire mathematics subtest scale score for the two grade levels. As is common in educational studies, an alpha level of .05 was set for the two-tailed test of each null hypothesis (Siegle, 2009).

Summary

A well-written PBL mathematics curriculum may assist educators desiring to implement PBL to increase students' ability to transfer knowledge. Both adults and students in the United States have been unable to demonstrate the ability to transfer mathematical knowledge to new problem situations. Proponents of PBL, based on constructivist learning theory, have suggested that students learning in problem-solving environments will develop logical structures that allow them to apply knowledge to various new problems and situations. Implementation of PBL requires carefully chosen problems that fall with a student's zone of proximal development. Creating and finding these problems can be a challenge for educators; so, a well-written PBL curriculum may help educators teach mathematics.

The use of problem-based curricular materials assists educators in desiring to implement PBL. The OUR Mathematics curriculum used by the experimental group in this study is a freely available PBL curriculum. This study is designed to compare scores of students taught using OUR Mathematics curriculum to those who have used more traditional mathematics curricula. Chapter II includes a review of the literature. Topics include PBL, PBL in mathematics, gender, and family-income level.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Curricular materials play an essential role in the educational process. Developers of mathematics curricular resources often endorse a teaching style, such as PBL or more traditional instruction, and this endorsement affects educators and learners' experience. Slavin et al. (2008) explained that some textbooks focus on innovative strategies such as problem-solving, alternate solutions, and conceptual understanding; some include a more traditional balance between algorithms concepts and problem-solving; and some emphasize a step-by-step approach to mathematics. Educators choosing and using each of these different resources would likely also advocate an associated teaching style, and curricular materials choices may affect students' interactions with mathematics. According to Silver (1986), students working on story problems in traditional mathematics texts can often bypass the mathematical understanding of the problem by applying the operation emphasized in that section of the text. If this is true, students could obtain correct results without understanding the underlying mathematics. An educator's choice of textbooks or other curricular materials could influence instruction and alter students' learning experience.

An argument for using problem-based instruction is that it may ensure students have considered the underlying mathematical understanding as they have engaged in solving problems. Barrows (1986) asserted that PBL, grounded in authentic problems, developed a better reasoning process in students and better prepared them to apply previously-learned knowledge. The use of authentic problems might discourage the student practice of basing solutions to problems on only the operation used in a text. Hiebert et al. (1996) argued that while authentic tasks were useful, tasks that appeared routine to educators could be seen as genuine problems if presented at the right time. If Hiebert's assertion is correct, mathematics curricular materials employing a problem-based theory of learning might include both authentic and purely mathematical problems in the educational sequence to promote students' conceptual and procedural awareness of mathematical ideas. Employment of problem-based strategies might deepen students' understanding of mathematics, promoting applying knowledge in diverse situations. However, whether the deepened understanding of mathematical concepts translates to better performance on standardized assessments remains to be seen.

This chapter will provide a review of relevant literature detailing PBL and the theoretical framework of experiential learning and constructivism. A discussion of problem-based instruction, as applied in mathematics, will include the use of problem-based curricular materials. This chapter will also include a discussion of specific curricular materials implemented by the schools in this study, OUR Mathematics Curriculum, Eureka Math, and Big Ideas Math. The effects of gender and family-income level in mathematics will be summarized along with the influence of PBL-use on students of a different gender or family-income level.

Theoretical Framework: Constructivism

Constructivism emphasizes the experiences of the learner as central to the learning process. Constructivist learning theory is built upon the idea that reality is constructed based on the learner's experiences (Cooper, 1993), and therefore concrete experiences are an integral part of the learning process (Beard, 2018). Educators are employing constructivist theory approaches to create new experiences for the learner and promote new learning. Constructivist theory is based upon Dewey's (1938) theory of experiential learning, in which he stated that experience is the optimal stimulus for learning. Dewey claimed that social and interactive processes were essential to learning, and the role of the educator is to create an educative experience. An educative experience is an active, rather than passive, learning process. Educators employing practices based on experiential learning and constructivist theories attempt to create students' experiences to promote new learning.

Well-designed educational experiences promote both new learning and good judgment. Dewey (1938) explained that not all experiences are educational, and some experiences hinder growth. Experiences should be designed to activate the learner and promote desired learning. Dewey warned that growth could happen in an undesirable direction, such as helping one become a better thief. Dewey proposed that educators should provide experiences that help learners to judge wisely and evaluate their desires. Experiential learning is not about catering to learners' desires but includes experiences that help learners consider the consequences of following their desires. Educative experiences are designed to promote positive learner growth and judgment.

In constructivism, an extension of experiential learning theory, learning is described as a repeating cycle. Peterson and Kolb (2018) intimated that learning is a recursive cycle of concrete experience, reflective observation, abstract thinking, and active experimentation. This learning cycle is not linear but rather a cycle repeated as learners construct and deepen their knowledge. Peterson and Kolb proposed that learners in this cycle attend to the experience, reflect on its meaning, reason about the generalization of the experience to make a decision, and then act on the decision. This cycle would promote learners' critiques of ideas and desires, as Dewey (1938) recommended. Both constructivism and experiential learning theory describe learning as a repeating cycle resulting in more in-depth reflection and understanding.

Proponents of constructivism extend the experiential learning ideas by claiming that learners think about and reflect on knowledge and construct knowledge as they engage in problem-solving. Peterson and Kolb (2018) described changes in the learner required for new learning by saying, "…we accept that learning and change can only occur when the individual perception and meaning-making are interrupted" (p. 228). New learning requires an alteration of current thinking patterns. Cooper (1993) claimed that experiences determine a learner's reality and that learning is problem-solving based on personal discovery. Learners discover new ideas by solving and reflecting upon challenging problems. Learners construct knowledge as they experience and engage in challenging problems, and PBL was designed according to this theoretical background.

Problem-Based Learning

PBL, an application of constructivism, began as an adaptation applied during instruction to solve a learning problem rather than beginning as a theory developed independently from practical application. Barrows (1996) stated that PBL was developed in response to student claims that knowledge gained in medical school was largely irrelevant. Barrows claimed that PBL was developed at McMaster University Faculty of Health Sciences and was used during the 3-year curriculum cycle of medical school, with the class graduating in 1927. By 1967, PBL had been implemented in over 60 medical schools (Savery & Duffy, 1995) and expanded to other areas such as mechanical engineering, social work, optometry, architecture, nursing, legal training, business, and industry (Boud & Feletti, 1997). PBL extended into many fields in an attempt to make knowledge more meaningful for students. PBL was developed not in an office as an idea but by trial and error as educators were trying to make knowledge more applicable to and valuable for students.

PBL is an attempt to increase the practicality and applicability of the knowledge students gained in their studies. The original objectives for PBL included structuring knowledge for use in clinical contexts, developing an effective clinical reasoning process, developing self-directed learning skills, and increasing motivation for learning (Barrows, 1986). These objectives focused on the application of medical knowledge. A method was developed to meet these objectives in which ill-structured problems (problems with no clear solution path) were presented as they are in the real world. Learners assumed responsibility for their learning, teachers served as facilitators (tutors), and the authentic problems were those likely to be encountered during a student’s career (Barrows, 2002). The learner's role in PBL is like the role taken during a career where, as a part of a job, one faces problems to solve, takes responsibility for solving problems, and occasionally consults with others for potential solutions. The objectives and structure of PBL focus on what learners will be using and applying in their respective fields.

Students experiencing learning focused on using and applying knowledge may increase their abilities to acquire and use knowledge. Medical students in PBL environments performed as well or better on clinical examinations and evaluations, exhibited a higher degree of independent learning, considered PBL more enjoyable than traditional (tell and practice) methods, and placed greater emphasis on understanding the content (Albanese & Mitchell, 1993;

Vernon & Blake, 1993). In other fields, students experiencing PBL gained the ability to be self-directed learners, acquired content knowledge in context, and became better problem-solvers (Boud & Feletti, 1997; Margetson, 1997; Savery & Duffy, 1995). The stated results appear consistent across different fields of study. Learning in a PBL environment may be associated with greater pleasure in learning, the ability to apply knowledge learned, and the capability to acquire new knowledge.

Since PBL emphasizes the application of knowledge and problem-solving, implementation methods have been adapted as PBL has been applied to different fields of knowledge. Boud and Feletti (1997) hinted that translation of the method to a new context without some changes is seldom possible. Educators often take ideas and modify them to fit the students or the context. Barrows (1986) posited that in the original PBL clinical model, students were given a patient's presenting picture in a simulation format, the students were then allowed free inquiry, and finally, the teacher might have facilitated or tutored. In fields that have no patients, PBL required adaptation. Barrows added that PBL had been transformed to meet the needs of different fields of study, but the use of problems in the instructional sequence as the stimulus for learning is the defining characteristic of PBL. The instructional sequence may include posed questions, unexplained phenomena, or problems involving health or community. PBL may describe various related strategies, but PBL strategies follow the general steps shown in Figure 2, comparing the method to traditional instruction. Traditional learning is content-focused, and PBL involves working on a problem through which content is learned. Problem-solving is common to different adaptations of PBL into other learning contexts.

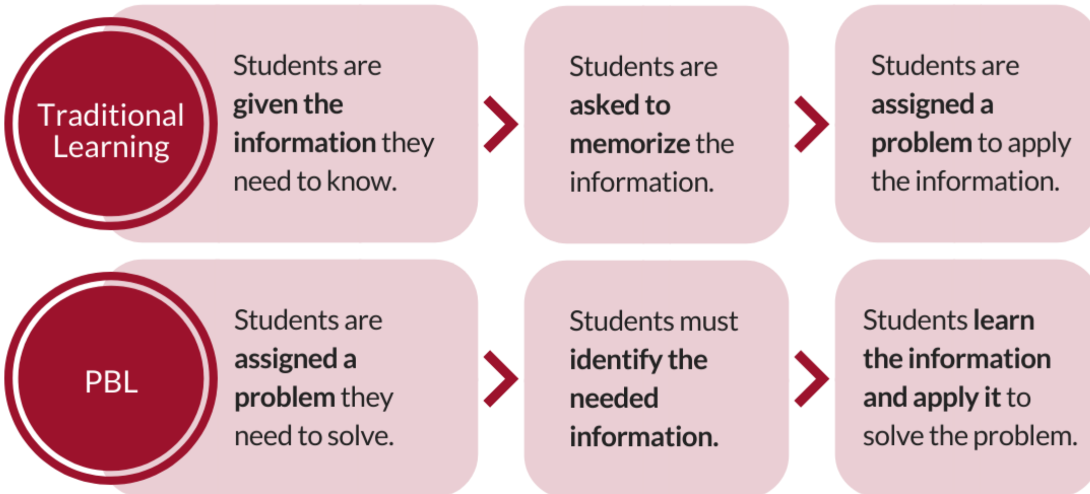

Figure 2: The PBL learning process. From "Problem-based learning" by Queen's University Centre for Teaching and Learning (2005). Reprinted with permission.

In problem-based learning, educators sequence problems in an order designed for students to construct knowledge by interacting with problems. Barrows (1986) claimed that in PBL, educators design and sequence problems, and students develop knowledge as they engage in the problems. Instructors in the PBL environment serve as facilitators rather than dispensers of knowledge. Barrows claims that teachers provide knowledge when students determine that knowledge is needed to solve a given problem. PBL is an application of Peterson and Kolb's (2018) recursive cycle of concrete experience, reflective observation, abstract thinking, and active experimentation. Students in PBL environments experience the problems as they reflect upon, think about, and experiment with posed problems. In PBL, students take time to ponder problems as their knowledge is constructed.

Since students in PBL environments construct knowledge through solving problems, PBL may take more time than other methods to gain an organized base of knowledge. Albanese and Mitchell (1993) noted that students learning through PBL processes sometimes scored lower than those learning in a traditional environment on general sciences exams. Since general sciences exams have typically measured basic knowledge and skills, this may indicate that basic knowledge and skills are more readily learned through other teaching methods. Albanese and Mitchell (1993) and Margetson (1997) noted disadvantages of PBL, including that PBL took more time, used more resources, and resulted in unpredictable or random learning. Two of these criticisms had to do with the cost, and a third was related to the learning. These criticisms may cause educators to pause as they consider implementing PBL.

PBL may take more time than other methods, and effective PBL implementation involves careful planning by educators. Boud and Feletti (1997) warned that PBL is not only adding problem-solving exercises to traditional curricula. Implementation of PBL involves an in-depth change in the materials and instructional facilitation methods used rather than a quick addition of problem-solving tasks. Boud and Feletti (1997) and Margetson (1997) argued that including appropriate structures and critical reflections on the learning process during PBL implementation facilitate discovery and make learning both reliable and predictable. PBL implementation requires careful planning of problems, structures, and student reflection. The problems must fall within the learners' zones of proximate development, as described by Vygotsky (2017). If students are to construct knowledge as they engage in problems. If a problem is too easy for students or so difficult that students cannot engage effectively in the problem, learning is unlikely to occur. Educators wishing to implement PBL must plan and work to ensure effective implementation.

Despite the work required, those in many different educational settings began using problems as the basis for learning. A method launched in the medical field to increase student motivation and diagnose problems has affected many other fields, including mathematics classes in public schools. Implementation in all these fields was intended to encourage learners to construct and apply knowledge.

Problem-Based Learning in K-12 Mathematics

The use of PBL expanded from medical and technical fields into public schools, and promises of student mathematical learning and problem solving motivated some mathematics instructors to move toward a problem-based approach. The first formal record of PBL used in K-12 school mathematics programs was the Problem Based Learning Institute (Barrows, 1996). Some elements of PBL were integrated into mathematics before that time. For instance, Schoenfeld (1988) demonstrated that teaching only for procedural understanding could interfere with students' abilities to learn new mathematical concepts and recommended posing mathematical problems to develop student understanding. Instructors implementing this approach would have been engaging some aspects of PBL. Later, Carpenter, Ansell, Franke, Fennema, and Weisbeck (1993) discovered that children could solve a wide range of problems much earlier than generally had been presumed and could solve problems based on modeling the problem rather than requiring pre-teaching of methods or algorithms. According to Carpenter et al. (1993), the prevailing belief before this time was that children must be taught algorithms or problem-solving methods before they can solve problems. Students learning by actively modeling problems is one characteristic of PBL. PBL teaching methods were developed to engage and build upon existing student modeling and problem-solving skills.

Classrooms in which students actively use existing knowledge to engage in problems to understand mathematics have been described using several names. Approaches with these characteristics have been called problem-based learning (Barrows, 1986; Boaler, 1998; Erickson, 1999; Walker, 1999), a problem-solving approach (Erickson, 1999), reform mathematics (Erickson, 1999), open-ended mathematics (Boaler, 1998), constructivist mathematics (Walker, 1999), student-centered mathematics (Saragih & Napitupulu, 2015; Walker, 1999), and open mathematics (Boaler, 1998; Erickson, 1999). Although these approaches may vary, making sense of mathematical situations and problem-solving are integral elements of each approach. PBL, by any name, is an instructional process in which students are expected to reason about and solve problems.

Problem-Based Learning as Active Learning Through Problem Solving

PBL involves learning through active student engagement in mathematical problems. Davis (1986) argued that doing mathematics was a process of thinking, not just symbolic manipulation. He claimed that doing mathematics involved creating a mental representation of the problem and some relevant knowledge to creating a solution. This idea parallels Piaget's (1975) theory that students construct logical structures as they engage in problems. Erickson (1999) later contended that problem-solving tasks could inspire students to develop understandings of mathematical ideas and called for the implementation of PBL in mathematics. Learning mathematics by engaging in problems is an example of experiential learning, as Peterson and Kolb (2018) described. PBL applies experiential and constructivist theories by actively engaging students in doing mathematics.

The use of PBL in mathematics immerses students in the experience of doing mathematics. Davis (1986) compared doing mathematics to a movie where one hears the words on a script, but one's thoughts are on "...the action, the dialogue, and the development of characters..." (p. 266). From Davis's point of view, the joy of mathematics arises from developing and understanding mathematical ideas, just as the joy of seeing a movie includes the action, the dialogue, and character development. Students who do not develop mathematical understanding may miss out on the joy of mathematics, just as those who only focus only on the words in a movie would not truly experience the movie. Implementation of PBL in mathematics includes actively engaging students in problems to encourage student development of mathematical ideas.

Students in a PBL setting engage in problem-solving tasks, make sense of problems, and use their understanding to solve problems. Erikson (1999) described a problem-based approach as one in which students are given a problem-solving task, asked to make conjectures, asked to justify their thinking, and encouraged to discuss different strategies or approaches. He defined PBL as an approach in which students are expected to make sense of mathematical situations and solve problems with no well-defined solutions or procedures for solving. Even though Erikson's description did not necessitate an authentic context for all of the work as described by Barrows (1986), Erikson's description allowed for real-world problems, required the learner to take ownership of learning, encouraged the teacher to act as a facilitator, and made use of authentic problems as presented in Barrows (2002). Others, such as Hiebert et al. (1996) and Jensen (2015), have described a problem-solving approach as one that involved student sharing and discovery, made use of real-word problems, integrated learning of understanding with the learning of skills, emphasized both process and product, and may have used both student-created and teacher-created problems. All of these characteristics of a problem-solving approach were intended to encourage a more in-depth understanding of mathematics. Students engaging in PBL of mathematics are expected to make sense of mathematics as they engage in different types of challenging problems.

Problematizing Mathematics

In mathematics, both authentic problems and routine problems can engage learners in investigating mathematical relationships. Authentic mathematics problems (ill-structured problems that might be encountered outside of an educational setting) were used in the Problem Based Learning Institute, the initial implementation of PBL in mathematics (Barrows, 1996). Traits of PBL, initially developed in the medical field, were transferred to a public-school mathematics environment. Barrows (2002) and Savery and Duffy (1995) argued that in PBL, problems must be authentic. However, Hiebert et al. (1996) ascertained that tasks that may appear routine (structured problems having no context or a made-up context unlikely to be encountered outside of an educational setting) to teachers might seem authentic to students. He asserted that problems are not inherently problematic nor routine, and teachers should *problematize* the subject rather than requiring mastery and application of skills. A problem would be problematized if presented so that learners engage in a problem to understand the concept before seeing solution methods. Hiebert et al. (1996) argued that mathematical understanding, organizing information in ways that highlight relationships between ideas, is more important than the type of problem used. The relational thinking described by Heibert et al. differed distinctly from mathematics in classrooms, where each day involves memorization and practice of a new mathematical procedure. When implementing PBL, both routine and authentic problems may promote a learner's discovery of mathematical relationships and ideas.

Problematizing mathematics, however, involves more than merely adding problems to an existing instruction. Instead, it requires changing the entire system of instruction so that learners participate in a community of people who practice mathematics (Hiebert et al., 1996). This community of practitioners represents an application of Vygotsky's (2017) social constructivism.

In a mathematics community, students see themselves as participants rather than spectators of mathematics. Students in a PBL environment make reasoned conjectures about problem-solving tasks, justify their thinking, and listen to and consider others' ideas (Erikson, 1999). These actions describe the work of mathematicians. Mathematicians regularly engage in problem situations unfamiliar to them and consider engagement in problem-solving the nature of mathematics. Problematizing mathematics involves encouraging students to think and react as mathematicians who make conjectures and explore ideas within a community of learners.

Problem-Based Learning Implementation and Student Achievement and Attitudes

If the implementation of PBL encourages students to think like mathematicians, this thinking should translate to student success in mathematics. For instance, Jensen (2015), Ridlon (2009), Rosli et al. (2014), Şad et al. (2017), Trinter et al. (2015), and Yancy (2012) indicated increased student achievement in mathematics as a result of PBL implementation. However, Boaler (1998) noticed only a small effect of PBL on student achievement compared to more traditional methods. Despite this disparity, PBL implementation appears to overall positively impact student achievement in K-12 mathematics. However, overall achievement is only one measure of the success of students in mathematics.

Problem-solving represents another measure of student achievement. Ridlon (2009) and Rosli et al. (2014) conducted studies revealing large positive effects of PBL implementation on problem-solving abilities in mathematics. However, Maree and Molepo’s (2005) study revealed no difference with the implementation of PBL on problem-solving behavior. Even though Maree and Molepo reported no significant difference in PBL implementation on students’ problem-solving ability, overall PBL implementation appears to affect students' problem-solving ability positively. Boaler (1998) found that those taught using PBL demonstrated significantly higher scores on application and problem-solving tests than those taught using traditional methods. She reported that students taught using traditional methods believed they should remember a rule or equation to solve problems rather than consider different methods that might be used to approach the problem. PBL may encourage students to consider different problem-solving methods. Dewey (1930) mentioned that in constructivism, students learn as they critique ideas. Considering different problem-solving methods involves a critique of the methods to determine which methods are viable to solve the given problem. Student mathematics achievement and problem-solving abilities are not the only measures that appear to be affected by PBL implementation.

Student attitudes towards mathematics are essential to students' success in mathematics. Boaler (1998), Ridlon (2009), and Rosli et al. (2014), observed more positive student attitudes toward mathematics with PBL implementation; however, Maree and Molepo (2005) observed no difference with the implementation of PBL on student attitudes towards mathematics. Overall, PBL appears to have a positive effect on student attitudes toward mathematics. Positive attitudes toward mathematics could affect student success in mathematics. Ridlon (2009) reported that students taught using PBL methods felt empowered because their ideas were valued. Students who believe their ideas are valued may be more likely to adapt their ideas to new problem situations. Boaler (1998) asserted that students' beliefs that mathematics is adaptable, rather than rigid, were associated with student achievement. Students who see mathematics as adaptable may also be more likely to see value in conceptual rather than procedural mathematical knowledge.

Conceptual and Procedural Knowledge

Conceptual and procedural knowledge are crucial to mathematics as mathematicians often make conjectures and work to understand a problem before arriving at a problem solution. Both conceptual knowledge (often referred to as conceptual understanding) and procedural knowledge (procedural fluency) are essential in mathematics (Carpenter, 1986; Hiebert et al., 1996; Laswadi, Yaya, Darwis & Afghani, 2016; Rittle-Johnson, Schneider, & Star, 2015; Wu, 1999). Mathematics instruction can aid the development of conceptual and procedural mathematics knowledge.

Conceptually-focused instruction may increase both types of knowledge. Evidence has indicated that teaching methods, including a focus on conceptual understanding, resulted in increased conceptual and procedural knowledge (Canobi, 2009; Pesek & Kirshner, 2000) and increased students' later mathematical development (Hecht & Vagi, 2010). Teaching focused on conceptual knowledge resulted in increased knowledge of other types. Conceptually-focused teaching increases both conceptual and procedural knowledge, which are both needed for students' mathematical development.

Traditional learning alone may not lead to conceptual understanding. Students in one causal-comparative study who received only relational instruction (instruction for meaning and understanding) outperformed those who received only procedural instruction and those who received a mix of procedural and relational instruction (Pesek & Kirshner, 2000). Schoenfeld (1988), in a case study involving 11 geometry classes with 2010 subjects, reported that many students who performed well on traditional assessments could not apply the knowledge they had proven in one question to a construction question requiring the application of that knowledge. Even though these students could write a proof, they did not demonstrate understanding allowing them to apply their knowledge. Procedural knowledge without conceptual knowledge appeared to affect the usefulness of students' mathematical knowledge.

Students who learn procedural knowledge without conceptual knowledge may exhibit more learning misconceptions. Learning procedures did not ensure usable knowledge had been acquired (Carpenter, 1986), and procedural fluency without conceptual understanding led to many common procedural flaws or misconceptions (Silver, 1986). Kamii and Dominick (1997) indicated that a group of third- and fourth-grade students who were asked to understand and invent their own procedures for number operations correctly answered more questions and demonstrated more mathematical understanding with fewer misconceptions than the group that was taught procedures. They also found that the taught-procedures group exhibited more severe misconceptions than those in the invented-procedures group. Students' conceptual knowledge did not appear to increase and may have been harmed by rote learning of procedures. Boaler (1998) reported that students in a traditional learning environment developed cue-based behavior in which they tried to access the procedural knowledge they believed was expected in a given situation and often did not base choices on the context of the problems. Learning procedures without conceptual knowledge may lead to the misapplication of mathematical knowledge. Both conceptual and procedural knowledge may be necessary to promote the flexible use of knowledge in learners.

While both conceptual and procedural knowledge are essential, disagreement exists about when and how to promote learners' conceptual knowledge. NCTM (2014) claimed conceptual understanding should be taught before learning procedures; however, Rittle-Johnson and Koedinger (2009) indicated that students receiving concepts-first instruction and those receiving mixed instruction of concepts and procedures had similar achievements and demonstrated similar conceptual knowledge. The order in which conceptual and procedural knowledge was learned may not matter. Students gained conceptual understanding through abstraction of procedures (Siegler & Stern, 1998), and other students receiving procedural instruction achieved at the same level as those receiving conceptually focused instruction (Perry, 1991). The success of procedurally focused instruction in these studies illustrated that conceptually-focused instruction is not the only way to increase students' conceptual knowledge. Many agree that conceptual and procedural knowledge are essential, but no clear indication exists that one type of knowledge follows the other.

Procedural knowledge and conceptual knowledge each promote learning of the other type of knowledge. Conceptual and procedural knowledge have been predictive of each other (Rittle-Johnson et al., 2015; Schneider, Rittle-Johnson, & Star, 2011). Hiebert and Lefevre (1986) and Wu (1999) argued that meaningful learning includes the relationship between conceptual and procedural knowledge, and instruction should focus on both. Instruction emphasizing both types of knowledge may assist students in making connections among mathematical ideas. PBL emphasizes both conceptual and procedural knowledge.

Implementation of PBL may lead to increases in procedural and conceptual knowledge. Problem-solving requires the application of both conceptual and procedural knowledge (Silver, 1986). Implementing problem-based methods in the classroom has led to increased conceptual understanding and procedural knowledge (Inpinit & Inprasit, 2016; Laswadi et al., 2016). However, other researchers comparing the two methods, such as Boaler (1998) and Wilson, Nazemi, Jackson, and Wilhelm (2019), have determined that PBL implementation resulted in increased conceptual understanding but no significant change in procedural knowledge. Evidence from the studies mentioned seems to indicate that PBL positively affects conceptual knowledge and does not negatively affect procedural knowledge. Walker (1999) performed an item analysis of TIMMS test items and reported that students learning in a student-centered environment performed slightly better than students taught using other methods on achievement test items measuring conceptual understanding. PBL implementation appears to have resulted in increases and conceptual knowledge and, in some cases, increased procedural knowledge. Learning of both conceptual and procedural knowledge through PBL may allow students to apply their knowledge better.

Problem-Based Learning and Learning Transfer

Knowledge becomes more flexible as learners strive to apply their understandings in different contexts. While applying strategies in different situations, students are provided with the opportunity to adapt and change (Roh, 2003). Any learning requires some change. Learners who struggled as they obtained knowledge demonstrated increased transfer (ability to apply in new situations) of knowledge (Boaler, 1998; Hiebert & Grouws, 2007; Jonsson, Kulaksiz, & Lithner, 2016; Schoenfeld, 1988). Learners in PBL environments may experience struggle as they adapt and change to new problem situations, but learning occurs amid this struggle. Although learners may struggle to use knowledge in new situations, this struggle may better prepare them to transfer their knowledge.

One measure of learning is the ability to apply knowledge learned in new situations and new ways. Young (1993) claimed that the real learning test is the transfer of knowledge from the learning situation to a novel situation. If mathematics is to be useful outside of a classroom setting, transfer of learning is required. Billing (2007) described low-road transfer as the ability to apply knowledge in situations like the context in which it was learned. He described the high-road transfer as the ability to extract principles underlying existing knowledge and apply them to novel situations. The high-road transfer would require both procedural and conceptual knowledge of mathematics used. Billings also noted that rote learning of facts discouraged transfer, and learning principles and concepts encouraged the transfer of knowledge. Facts are essential, but more understanding may be needed to make the knowledge useful in new situations. Learning is useful when it can be applied in situations that differ from the learning context.

A variety of teacher and student practices promote the transfer of learning. VanderStoep and Seifert (1993) posited that teaching why a formula applies to a given situation promoted better transfer than teaching how to apply it to a situation. Thinking about why a formula applies may promote a deeper understanding of the formula, allowing for better knowledge transfer. McGraw and Patterson (2017) noticed that learners working on tasks where all needed information was provided were hesitant to consider external information or set up boundaries on open-ended problems. Considering external information and considering problem boundaries are essential for the effective transfer of learning. Researchers have also noted transfer is promoted by dialogue and reflection (Nelissen, 2016); student struggle (Jonsson et al., 2016); and focusing student noticing on critical mathematical ideas (Lobato, Rhodehamel, & Hohensee, 2012). Implementation of PBL, as described by Barrows (2002) and Erickson (1999), would include the practices mentioned. If PBL includes the practices mentioned above, it follows that PBL implementation should promote more significant knowledge transfer than other teaching methods.

Some instructional approaches appear to have no significant effect on student transfer of learning. Belenky and Nokes-Malach (2013) compared groups taught using a tell-and-practice strategy to those being encouraged to invent strategies to solve problems and found no significant difference in transfer. Jitendra, Star, Dupuis, and Rodriguez (2013) reported that while students receiving schema-based instruction (instruction explicitly teaching problem structures, encouraging the use of visual representations, including heuristics, and emphasizing multiple strategies) outperformed the control group (traditional instruction) on problem-solving, both groups performed similarly on measures of transfer. Schema-based instruction and instruction encouraging student invention of strategies did not significantly affect the transfer of knowledge when compared to traditional instruction.

PBL implementation may promote increased student ability to transfer knowledge. Kapur (2014) found that students receiving unguided problem-solving tasks before instruction, as is common in PBL, exhibited higher transfer than both those who received direct instruction and those who received guided problem-solving instruction first. Allowing students to struggle with the problem first may increase the ability to transfer knowledge to new situations. Similarly, Schalk, Schumacher, Barth, and Stern (2018) discovered that students presented with problems before instruction were better able to transfer knowledge than those receiving tell-and-practice instruction, common in traditional instruction. Schalk et al.'s results appear to validate Heibert et al.'s (1996) claim that non-contextual tasks can be considered problems for use in PBL if presented at the right time. Boaler (1998) reported that students in a school implementing PBL were better able to apply their knowledge compared to students in a school receiving traditional instruction. The ability to apply knowledge in new contexts is evidence of the transfer of knowledge. Learning in a problem-based setting appears to affect students' ability to transfer knowledge positively.

Problem-Based Mathematics Curricula

Curricula for problem-based instruction were developed to engage students in the process of learning mathematics. The development of problem-based curricula began as early as 1927 (Barrows, 1996). Early PBL adopters noticed the need for curricular materials. According to Senk and Thompson (2003), problem-based curricula were often called standards-based curricula because of attention to mathematics content and process standards and were outlined in the 1989 publication, *Curriculum and Evaluation Standards for School Mathematics*, by the National Council of Teachers of Mathematics. Process standards describe how students are to reason with mathematical content and include reasoning about mathematical problems. The reasoning described in the process standards aligns with Barrows' (1996) assertion that students develop knowledge to solve problems. Problem-based curricula are designed to engage students in solving problems, which is a learning process for students.

Because of an emphasis on the learning process, problem-based curricula contain different types of problems and exercises than traditional mathematics curricula. Senk and Thompson explained that standards-based (PBL) curricula contained more problem-solving tasks, contained fewer exercises requiring only memorization or application of algorithms, and emphasized engagement and problem-solving. While some curricula appear to be focused on learning (algorithms and facts), PBL curricula were designed to engage students in the learning process by using mathematical problems. Bergqvist and Bergqvist (2017) highlighted six mathematical competencies: problem-solving ability, reasoning ability, representation ability, connection ability, communication ability, and applying procedures ability. They proposed that curricula emphasizing the first five of these competencies represent a more problem-based message, and curricula emphasizing the content and applying procedures competencies represent traditional mathematics. Problem-based materials use engaging problems to encourage students to reason about, represent, and communicate mathematical ideas.

Problem-based curricula assist instructors as they attempt to engage students in reasoning, communication, and problem-solving. According to Barrows (1996), problem-based curricula have provided problem collections to keep learning on track, learning objectives associated with problems, and guidelines to assist with the transition from traditional to problem-based instruction. Problem-based curricula are designed to assist educators with the time-consuming challenge of choosing problems to meet different mathematical objectives. Boud and Feletti (1997) argued that problem-based curricula were needed because of the difficulty of translating a given approach to another context without modification. Translating problem-based learning from one context to another would require consideration of both the subject objectives and the zone of proximal development of students involved. Problem-based curricula may ease educators' burden by providing problems that are likely to engage students in problems on their level that align with the course or grade-level objectives.

Problem-Based Learning Curricula and Measures of Student Success

If curricula are aligned to students' ability and grade level, one might expect to see differences in student success measures using the curricula. Students using standards-based curricula and those using traditional curricula have scored similarly on measures of student achievement (Cai et al., 2011; Harwell, Medhanie, Post, Norman, & Dupuis, 2012; Mathematica Policy Research & What Works Clearinghouse, 2017; Ridgeway, Zawojewski, Hoover, & Lambdin, 2003; Ridlon, 2009, Tarr et al., 2008). However, Nargi (2018) indicated that students learning with a problem-based curriculum scored lower on mathematical achievement measures. Overall, the use of problem-based curricula appears to have little or no effect on traditional measures of student achievement. However, one may ask if the implementation of problem-based curricula affects student success in other ways.

Students' transfer of learning, attitudes towards mathematics, and motivation to learn mathematics are also essential success measures in mathematics. The use of problem-based materials has been linked to increases in students' skills in solving more complex problems (Budak, 2015; Cai et al., 2011; Ridgeway et al., 2003). Students' engagement in problems provided in the curriculum may lead to greater abilities to solve other complex problems, which is evidence of learning transfer. Saragih and Napitupulu (2015) observed that students using problem-based materials improved mathematical thinking ability, exhibited more positive attitudes towards mathematics, and displayed greater motivation. Ridlon (2009) also noticed more positive student attitudes with the implementation of problem-based curricula. Increased thinking ability, attitudes toward mathematics, and motivation parallel the attitude changes and content understanding noticed by Vernon and Blake (1993) with PBL implementation in other study fields. The studies of curricula discussed here were not studies exploring the specific curricula used in this study, but similar results might be expected based on the curricula types.

Open Educational Resources

Some curricula used in this study are open educational resources. According to Atenas and Havemann (2014), open educational resources are teaching and learning materials that are freely available and openly licensed. Hylén, Van Damme, Mulder, and D'Antoni (2012) wrote that open educational resources were made initially available for higher education and are now available at all education levels: primary, secondary, and higher education. Free, openly licensed materials can be used at little or no cost by school districts. Open resources' benefits include innovative potential, cost efficiency, increased efficiency and quality, and open and flexible learning opportunities (Hylén et al., 2012). Many curriculum adopters could be drawn to open resources for the cost and efficiency benefits alone. Whatever the reason, the popularity of the materials is increasing at all levels.

Open educational resources seem to be as effective as commercially available materials. Hylén et al. (2012) claimed that open educational resources are not covered well by research. Most available research studies investigating open educational resources focus on social or economic issues such as widening access to resources or lowering the costs of resources. However, Hilton, Larsen, Wiley, and Fischer (2019) compared students' mathematics achievement scores and reported that open educational resources were as useful as commercial resources. Although only one study comparing open educational resources to commercially available materials could be found, one would not expect a difference in the use of open educational resources on student achievement since open educational resources are defined by the distribution method rather than on the quality of materials. With that in mind, the focus needs to be on the quality of specific materials or curricula.

Open Up Resources Mathematics Curriculum

The OUR Mathematics curriculum was designed to offer a free, high-quality, problem-based curriculum to Grades 6-8 mathematics educators. According to OUR (2019), the OUR mathematics curriculum began as a 13-state initiative funded by the Gates Foundation and OUR to provide equitable access to a quality curriculum. OUR worked with experts from Illustrative Mathematics to write a curriculum made freely available as an open educational resource (OUR, 2019). If the freely available mathematics curricula are of high quality, school districts could adopt the curriculum without the financial burden of commercial curricula, thereby increasing equity among districts with differing financial resources. According to Illustrative Mathematics (2019), the OUR Mathematics Curriculum is a problem-based curriculum aligned to the content and practice standards outlined in the *Common Core State Standards for Mathematics*. Illustrative Mathematics claimed that students using the curriculum would learn by doing mathematics, would solve problems in mathematical and real-world contexts, and would construct arguments using precise language, which aligns with characteristics of problem-based curricula as described by Bergqvist and Bergqvist (2017). The problem-based OUR Mathematics curriculum is designed to provide more equitable access to mathematics instruction.

To further encourage equity, the OUR Mathematics Curriculum was designed to aid teachers in implementing effective practices. According to Illustrative mathematics (2018), the curriculum was designed so that conceptual understanding and procedural fluency are taught together. Mathematics problems are sequenced to engage students in problems, and mathematics problems increase in sophistication to deepen students' understanding of mathematical relationships and expertise in mathematics. This approach, similar to that described by Hiebert et al. (1996), allows students to experience mathematics being learned and then revisit the same topics in other problems in the sequence to gain a deeper understanding. Illustrative Mathematics (2018) further asserted that the materials contain instructional strategy ideas associated with specific parts of lessons to encourage effective practices. According to Slavin et al. (2008), curricular programs that affect daily teaching practices and student interactions have more substantial effects on achievement measures than those emphasizing content or technology alone. If the materials are quality materials and promote effective teaching practices, educators may see increased student achievement.

Open Up Resources Use, Quality, and Student Achievement

The OUR Mathematics curriculum received high ratings from curricula evaluators and was adopted by several school districts. The OUR Mathematics Curriculum has been evaluated by EdReports, an independent organization that evaluates curricula on focus and coherence, rigor and mathematics practices, alignment, and usability. OUR 6–8 Mathematics curriculum received the highest rating among middle school mathematics programs on EdReports and was the only curricula rated to meet expectations in every category (EdReports.org, 2020; Illustrative Mathematics, 2018). The high ratings by EdReports may be related to the design of the curriculum described earlier. With the high evaluation ratings and free avaIlability of the curriculum, one may expect widespread use, and according to Business Wire (2018), by December 2018, over 200 districts and 300,000 students had used the mathematics curriculum. Since the curriculum was launched in 2017, many districts had adopted the curricula soon after the initial release.

While high evaluation ratings and popularity of the curriculum are positive indicators of successful curricula, they are not measures of student success.

No formal studies on the effect of the OUR Mathematics curricula on student achievement could be found, but educators' descriptions of the effect on student achievement appear promising. According to Business Wire (2018), teachers implementing the curriculum reported more student engagement and indicated they were surprised by what the mathematics students could do. Students in these classes appeared to have responded positively to the expectations of problem-solving. Powers (2019), a seventh-grade teacher using the materials, reported increased student achievement results for all students and subpopulations of students (including economically disadvantaged students) using the OUR Mathematics Curriculum. Limited teacher testimony indicates that the use of OUR Mathematics resources may positively influence student achievement, but no scientific studies investigating the OUR mathematics curriculum were found.

Eureka Math (EngageNY) Curriculum

The Eureka Math curriculum was initially developed as an open education resource. According to Great Minds (2016), the Eureka Math curriculum was founded by the non-profit Great Minds in 2007 and developed by classroom teachers and mathematicians across the United States in collaboration with New York state. The Eureka Math curriculum is freely available as an open educational resource under the curriculum's original name, Engage NY (Great Minds, 2016; New York State Education Department, 2020). Similar to the OUR mathematics curriculum, Eureka Math is freely available for use by educators. Eureka Math also received high ratings when evaluated by

EdReports. According to Heitin (2015), the EdReports ratings of Engage NY (now also called Eureka Math) were higher than the ratings of any other middle school mathematics curricula in 2015. These ratings remained the highest ratings for middle school mathematics curricula until the release of the OUR mathematics curricula in 2017. OUR Mathematics and Eureka Math Curricula share more characteristics than being freely available and receiving high ratings.

The Eureka Math curriculum also shares the OUR mathematics curriculum goals of building both conceptual and procedural knowledge; however, differences exist in the way Eureka math is designed to reach those goals. Diniz (2020) claimed that the Eureka Math curriculum was designed using learning progressions to teach mathematics as a coherent body of knowledge to build in-depth conceptual and procedural knowledge (fluency). Diniz explained that fluency requires understanding, not just obtaining answers. Both the OUR Mathematics Curricula and the Eureka Math Curricula were designed to help students gain procedural knowledge through understanding; however, the two curricula' instructional approaches differ. The OUR mathematics curriculum aligns with descriptions of problem-based texts described by Bergqvist and Bergqvist (2017), while Eureka Math contains fewer elements of problem-based curricula and more elements of traditional texts as described by Slavin et al. (2008). The Eureka Mathematics curriculum is designed for more direct teacher instruction. Educators using the Eureka Math curriculum would teach both conceptual and procedural knowledge using more traditional rather than problem-based methods.

The Eureka Math Curriculum gained quick popularity and resulted in reports of success from educators using the curriculum. According to Great Minds (2016), within 3 years of the release of the Engage NY curriculum (later known as Eureka Math), it became the most widely used mathematics curriculum in the United States. According to data stories posted on the Eureka Math (2020) website, several districts reported gains in student achievement measures after adopting and using the curriculum, such as an average gain of 16 percentage points on the Smarter Balanced assessment after 4 years of curriculum implementation in nine partner elementary schools in Los Angeles, 4.4 average percentage point gains on the TNReady Mathematics achievement test across all grades in Jackson-Madison County Public Schools in Tennessee, and 7.3 average percentage points gains on the Grades 3-8 state LEAP test in West Feliciana Parish Schools near Baton Rouge, Louisiana. Several districts reported increases in the percent of students scoring proficient and above (or equivalent) on achievement tests in their areas: Shelby County Schools, Memphis, Tennessee; Detroit Public Schools, Michigan; St. James Parish Schools, Louisanna; Iberia Parish Schools, Louisiana; Washington DC schools; and Public Charter Schools, Oakland, California (Eureka Math, 2020). The data described by these districts appear to indicate student achievement gains using Eureka Math; however, no scientific studies supporting this assertion could be located.

Big Ideas Math Mathematics Curriculum

Big Ideas Math is a commercially available curriculum emphasizing traditional instruction. According to Big Ideas Learning (2019), the commercially available curriculum represents a balanced approach of discovery and direct instruction based on learning and instructional theory. The curriculum includes reasoning opportunities, engaging activities for understanding examples with steps, thought-provoking exercises, and sequencing, which builds on previously taught material. The description suggests a blending of traditional and PBL approaches. Each lesson begins with an inquiry activity and then direct instruction (Big Ideas Learning, 2019). Slavin et al. (2008) claimed that a traditional text might contain inquiry activities, but instruction focuses on content and procedures rather than on problem-solving. Since the bulk of the text is content and procedure-focused, Big Ideas Math might best be described as a traditional commercial textbook curriculum and contains more traditional instruction elements than either the OUR or the Eureka Math curriculum.

Even though the Big Ideas Math curriculum may be described as a traditional curriculum, it contains several features that may be useful to educators and students. The authors of Big Ideas Math emphasized both conceptual understanding and procedural fluency (Big Ideas Learning, 2019). Hiebert and Lefevre (1986) claimed that an emphasis on procedural and conceptual understanding, regardless of instructional methods, resulted in increased student achievement. The authors of the text blended both types of understanding. Intervention strategies were embedded in Big Ideas Math with the inclusion of more in-depth supplemental materials. (Big Ideas Learning, 2019). Educators may assist in meeting the diverse needs of learners using provided intervention materials. Big Ideas Math supplemental resources also contain technology connections. Educators could blend instructional practices for students using technology resources. Big Ideas Math contains several aids for educators; however, no studies of Big Ideas Math's effectiveness could be located.

Gender and Mathematics Achievement

Historically, males and females have performed differently on measures of mathematics achievement. Since the 1970s, researchers such as Awofala (2017); Fennema (1974); Fennema and Hart (1994); Hyde, Fennema, Ryan, Frost, and Hopp (1990); Voyer and Voyer (2014) have noticed a gender gap in mathematics achievement. Recently, Guven and Cabakcor (2012), Pomeroy (2016), Fennema (1974), Reilly et al. (2015), Moore (2015); and Witonski (2013) reported the achievement gap might be closing or nonexistent, but Robinson and Lubienski (2011) reported the gap favoring males in mathematics achievement is widening. Overall, the evidence indicates a difference in males' and females' performance in mathematics achievement measures. This difference could be grounds for investigating the mathematics performance of males and females more closely.

Males and females may experience divergent rates of growth in mathematics achievement. After following students from the beginning of kindergarten through their eighth-grade year, Robinson and Lubienski (2011) reported that mathematics achievement scores were similar in kindergarten and lowered through elementary school so that females' scores were lower than males by eighth grade. Similarly, Ai (2002) reported that females started school with higher mathematics achievement than males but had a slower growth rate. These differing rates of growth may contribute to the gender gap in mathematics. If differences in mathematics achievement of males and females are considered critical, this change in achievement over time could be the pretext for further exploration.

Career Choices and Attitudes Towards Mathematics by Gender

The gender gap in mathematics may influence students' career choices, and this influence may be a reason to investigate gender differences in mathematics. Compared to males, females are underrepresented in science, technology, engineering, and mathematics (STEM) fields (Fennema & Hart, 1994; Reilly et al., 2015). Boaler, Altendorff, and Kent (2011) asked if females' career choices could be affected by differences in mathematics achievement and if other factors such as class choice or interest contributed to differences in males' and females' career choices. Boaler et al. noticed that males participated in more advanced mathematics classes than females. Advanced mathematics classes have been a gateway to many STEM careers. Pomeroy (2016) determined that females were less likely than males to express interest in a mathematics-related career. Mathematics achievement could affect students' choice of mathematics courses taken in high school and choice of career. However, other factors such as attitude towards mathematics could affect both achievement and choices made by students.

Males and females may also differ in their attitudes towards mathematics. Compared to males, females reported more anxiety (Hyde et al., 1990) and less self-confidence (Çiftçi & Yildiz, 2019) in mathematics. Anxiety and lack of confidence could affect mathematics achievement. Fennema and Hart (1994) and Hyde et al. (1990) reported females had a more negative attitude than males towards mathematics on measures of confidence, anxiety, and the perceived usefulness of mathematics, and according to Hyde, differences in attitudes increase as students age. This widening difference in attitude parallels a widening difference in mathematics achievement scores noticed by Robinson and Lubienski (2011). According to Pomeroy (2016), females reported feeling less confident about mathematics than did males, even when achievement test scores were the same. This evidence suggests that achievement may not be the sole cause of differences in attitudes towards mathematics. However, Ai (2002) discovered that attitudes toward mathematics were related to growth in mathematics achievement. Mathematics achievement and attitudes towards mathematics appear to be related in some way. Since attitudes could vary by country or culture, an investigation of males' and females' international comparisons may be warranted.

International Comparisons on Mathematics and Gender

Mathematics achievement, at the international level, may differ from mathematics achievement in the United States. After comparing international mathematics results, Else-Quest et al. (2010) reported evidence of males and females' overall similarity in mathematics achievement but found differing achievement of males and females in particular countries. In Nigeria, Awofla (2017) noticed correlations between gender and performance in mathematics. Awolfa's correlations could parallel the reported achievement gaps by gender in the United States (Hyde et al., 1990; Voyer & Voyer, 2014). In the United States, a difference was noted in both achievement and attitudes towards mathematics, causing one to ponder international attitudes towards mathematics by gender.

Internationally, attitudes toward mathematics by gender also differ from those described in the United States. Else-Quest et al. (2010) observed that males, in general, reported more positive attitudes than females towards mathematics, but this difference was not observed in every country. They found that, generally, students from nations with higher overall mathematics achievement expressed more negative attitudes toward mathematics. This finding could lead to consideration of a correlation between pressure to perform and attitudes towards mathematics. Awofla (2017) also reported connections between gender and attitudes toward mathematics in Nigeria. Similar to evidence of international mathematics achievement, no overall differences in attitudes towards mathematics were observed, but differences existed in particular countries, such as the United States (Fennema & Hart, 1994; Hyde et al., 1990). Attitude differences in particular countries that do not appear to exist internationally may be grounds for wondering if instructional practices such as the teaching methods used in classrooms may play a role in mathematics achievement or attitudes towards mathematics by gender.

Gender and Problem-Based Learning

Implementation of problem-based learning may affect the mathematics achievement and choice of mathematics courses of males and females. Ajai and Imolo (2015), Ojeleye and Awofala (2018), and Yancy (2012) reported that males and females scored similarly on mathematics achievement measures with the implementation of PBL. Boaler and Staples (2008) noted that no mathematics achievement gap by gender existed in schools implementing PBL, while a gap persisted in schools using traditional instruction. PBL may help narrow the achievement gap by gender and may affect males and females in other ways. Boaler and Staples, 2008 noticed that both males and females in schools implementing PBL progressed to higher mathematics courses than students in schools implementing traditional instruction (Boaler & Staples, 2008). These results may be grounds for considering the effects of PBL implementation on the choice of mathematics courses. If the implementation of PBL affects the mathematics achievement and attitudes of males and females, one might wonder if it also affects attitudes towards mathematics.

Males' and females' attitudes towards mathematics appear to be affected by the implementation of PBL. According to Boaler (1997, 1998) and Yancy (2012), males and females exhibited different attitudes towards traditional and problem-based mathematics instruction, but females expressed significantly more positive attitudes towards PBL. If females' attitudes are more positively affected, the gender difference in mathematics attitudes could narrow with PBL implementation. According to Boaler (1997), even though both males and females expressed dislike for traditional mathematics, females reported being more disaffected. Boaler noted that females' responses indicated their dislike of traditional mathematics was related to their desire to understand the concepts thoroughly, and males seemed more content to "play the mathematics game" (p. 292) by participating in mathematics they did not yet understand. Females seemed more dissatisfied in mathematics classes, emphasizing procedural knowledge rather than conceptual knowledge (understanding). Implementation of PBL affects males' and females' attitudes towards mathematics, which could provide grounds for consideration of reasons for further investigation of the effect of PBL on females' attitudes.

Females have reported several appealing characteristics of problem-based instruction. After analyzing results of a qualitative study, Schettino (2018) created a framework for mathematics instruction that included themes reported as noteworthy to females such as "(1) ownership of knowledge, (2) justification—not prescription, (3) the connected curriculum, and 4) shared authority" (p. 60). The themes outlined in this framework are typically present in PBL. Students are expected to be responsible for their learning (ownership), be able to explain why their solutions to problems make sense (justification), and view the teacher and others as facilitators of learning (shared authority). Additionally, curricular materials such as OUR, Eureka Math, or Big Ideas Math help ensure a connected curriculum. Females have responded positively to many themes that are often present in PBL. If specific instructional strategies worked for males and females, in general, they might work for other student groups in improving mathematics achievement.

Level of Family Income and Mathematics Achievement

Family-income level is referred to by different terms in research. Family-income level is often referred to as *socioeconomic status* or SES (Pomeroy, 2016; Sirin, 2005; White & Reynolds, 1993). School lunch status has often been used to measure family-income level and may refer to family-income levels using the term *school lunch status* (Boaler et al., 2011; Witonski, 2013). School lunch status was used in this study as a measure of family-income level.

Investigations by family-income levels are needed because low family-income levels may affect students' education. Reardon (2013) claimed that students from low-income households were less likely to attend college and scored lower on achievement tests. Reardon further explained that the achievement gap between children from low-income and high-income homes has widened in the last 30 years, while the achievement gaps related to other demographic characteristics, such as race, have narrowed. The observed achievement gap and decreased likelihood of college attendance may be the result of students' challenges from low-income families.

Challenges and Strengths of Students with Low Family-income Level

Students from low-income backgrounds face obstacles within their families and in the world outside of the family setting. Students from families with low-income levels may be affected by household disorganization (Garrett-Peters, Mokrova, Vernon-Feagans, Willoughby, & Pan, 2016), a lack of resources (Reardon, 2013), an increased likelihood of being raised in a single-parent home (Reardon, 2013), uneducated parents (Reardon, 2013), fixed mindsets (Claro, Paunesku, & Dweck, 2016), and lack of parental involvement (Gordon & Cui, 2014). These challenges in the family present possible obstacles to learning. Also, students with low-income backgrounds are less likely to participate in sports, academic clubs, civic activities, and community life (Reardon, 2013). Challenges such as household disorganization or lack of resources may place such a burden on students that participation in sports or clubs might be difficult. Students from households with low family-income levels may have many challenges but also may possess specific strengths.

Students' family-income level appears to be related to characteristics that may affect students positively and negatively. For instance, White and Reynolds (1993) discovered that students from families with low family-income levels scored lower than those from families with higher family-income levels. Similarly, White and British Columbia Teachers' Federation (2012) reported that many students with low family-income levels also have reduced attendance rates. However, White and British Columbia Teachers' Federation (2012) also noted many positive characteristics of these students with low family-income levels: the ability to verbalize their needs, to be sensitive towards other students, and to recover more quickly from setbacks. Adverse conditions associated with low family-income levels could cause challenges in some areas and build strengths in others. Therefore, the test becomes how these challenges and strengths affect performance in mathematics.

Family-Income Level and Mathematics Performance

Given the influence of family-income level on other areas of student learning, it would not be surprising to find that students' family-income level is related to their mathematics performance. Students having low family-income levels scored lower on measures of mathematics achievement than students with a higher family-income level (Alordiah, Akpadaka, & Oviogbodu, 2015; Boaler et al., 2011; Gustafsson et al., 2018; Pomeroy, 2016; Sirin, 2005). Overall, evidence suggests that family-income level affects student achievement. Childers (2015) revealed students in Arkansas with higher family-income levels performed better than those with lower family-income levels on the Arkansas End of Course Geometry Examination. Although the Geometry exam is not given to middle school students, one may wonder if middle school students in Arkansas would be similarly affected. Family-income level appears to negatively affect student achievement.

The belief that one is not a person who can achieve in mathematics or the belief that mathematics does not lead to a career might influence one's desire to engage in the subject.

Pomeroy (2016) reported that students with a higher family-income level reported more confidence in mathematics than students having a lower family-income level. Confidence in mathematics could affect achievement and desire to participate in the subject. Pomeroy further noted that students perceive mathematics as a subject in which only smart people excel and that students of low family-income level reported seeing sports, rather than mathematics, as a path to their future career. In this case, students' perceptions of their abilities may have affected their choice of career. Boaler et al. (2011) noticed that students with low family-income levels were less likely to participate in higher-level mathematics courses. Students' beliefs about their ability to achieve in mathematics may affect both mathematics courses and career choices. If a sub-group of students, such as those with low family-income levels, do not take higher-level mathematics courses, this could result in mathematics classes grouped by student sub-group.

Ability Grouping and Students with Low Family-income Levels

Ability grouping may affect the types of tasks students are given in mathematics classes. Pomeroy (2016) reported that ability grouping created classes segregated by family-income level and ethnicity, with top classes given high cognitive demand tasks and low classes given only low cognitive demand assignments. If students are not provided the opportunity to engage in rigorous mathematics because of the school setting, they may be unlikely to achieve at a rigorous level. If this is not the cause of the gap, it might widen an already existing gap.

Ability grouping may affect the overall quality of instruction received by students. Gustafsson et al. (2018) asserted that students of low family-income levels tended to receive lower-quality instruction. The students in most need of high-quality instruction may be the ones least likely to receive it. Gibbs and Hunter (2018) asserted that unless a teacher intervenes to encourage all students' participation, those who know more learn more and do not know as much learn less. They wondered if there was a way to combine students in classes while ensuring partition by all students in quality instruction. Dietrichson, Bog, Filges, and Jorgensen (2017) suggested that interventions such as tutoring, progress monitoring with feedback, and cooperative learning positively affect the achievement of students from low socioeconomic backgrounds. Implementing strategies such as these in classes that include students from both low and high family-income backgrounds may be one way to avoid ability grouping and narrow the achievement gap by family-income level.

Problem-Based Learning and Family-Income Level

Implementation of PBL requires all learners' participation (Barrows, 1986) and may also decrease the performance gap present by family-income level. Ridlon (2009) reported that students taught with a PBL approach exhibited improved student achievement, and students having low family-income levels demonstrated higher achievement gains than students from higher family-income levels. If the use of PBL leads to higher gains for students and more significant achievement gains for students with low family-income levels, then the use of PBL may assist in diminishing the achievement gap by family-income level. Holmes and Hwang (2016) and Hwang et al. (2018) observed that the mathematics achievement gap by family-income level narrows or remains about the same with PBL implementation. Vega and Travis (2011) and Witte and Rogge (2012) revealed that, at times, even when overall student achievement in mathematics did not significantly improve with PBL implementation, students with low family-income levels displayed significant gains. Using PBL may improve students' mathematics achievement with low family-income levels more than that of students with higher family-income levels. Because of PBL implementation's positive effect on students with low family-income levels, the use of the method may serve to narrow or close the achievement gap by family-income level.

Implementation of PBL could affect students' decisions to take higher-level mathematics courses in high school. Boaler et al. (2011) asserted that more problem-based mathematics practices would decrease differences by family-income level of students participating in higher-level mathematics courses after studying students' progress from middle school into high school. This assertion provides grounds for considering a possible effect of PBL implementation on students' participation in higher-level mathematics courses. The possible effects of PBL implementation on students from low family income backgrounds highlight the need to consider family income in the present study.

Summary

Implementation of PBL in mathematics differs slightly from the original PBL design but still uses problems, often found in problem-based curricula, as a learning tool. PBL, proposed by Barrows (1996) for use in the medical field, referred to using real-world problems as the stimulus for teaching. As the method spread to mathematics, PBL was modified to include both real-world and purely mathematical problems (Hiebert et al., 1996). If mathematical problems are used at an appropriate time, students may approach mathematical problems with the same sense of wonder and intrigue as they would real-world problems. Educators may use problem-based curricula as a resource for mathematical problems when implementing PBL (Boud & Feletti, 1997). Suitable materials may allow educators to focus on practical implementation rather than spending time searching for problems to use. Problem-based curricula include both real-world and mathematical problems for use by educators implementing PBL.

The use of PBL might affect student achievement and the ability to solve complex mathematical problems (Boaler, 1998, Budak, 2015); the performance of males and females on achievement measures (Boaler, 1998; Yancy, 2012); and the achievement gap by family-income level (Ridlon, 2009; Witte & Rogge, 2012). Given these possible effects, this study's focus was to explore the effects of a problem-based curriculum (OUR) on student achievement by gender and by family-income level. The goal is to increase the knowledge base of those making decisions about the use of curricular materials. Chapter III includes a discussion of the methodology used in this study, including a description of the research design, instrumentation, data collection, sample, data analysis, and limitations.

CHAPTER III

METHODOLOGY

The review of literature suggested that students can construct knowledge as they engage in and experience challenging problems as their teachers serve as facilitators of learning in PBL settings with PBL curriculum. PBL in mathematics has focused on problem-solving, reasoning, and communication to develop students' conceptual and procedural knowledge of mathematics. Mathematics curricula have been designed to facilitate educators with the implementation of PBL. PBL implementation may affect students' mathematical achievement, including attitudes towards mathematics and problem-solving abilities. Implementation of PBL could positively affect females and students with low family-income levels, groups that have scored lower on mathematics achievement measures. Information about the effectiveness of mathematics curricula, both with the entire student population and with specific sub-groups of students, is useful to educators making decisions about adopting curricula for use in middle school mathematics. This chapter discusses the research design, the sample used in the study, the instrumentation, the data collection procedures, the analytical methods, and the study's limitations.

Research Design

A quantitative, causal-comparative design was used in this study. A causal-comparative design was used because the grouping variables could not be manipulated, and the researcher was attempting to determine the cause for possible differences in the groups (Mills & Gay, 2019). Hypotheses 1-4 were tested using four 2 x 2 factorial between-groups designs. The independent variables for Hypotheses 1 and 2 were the type of mathematics curriculum (OUR versus traditional) and gender (male versus female). The independent variables for Hypotheses 3 and 4 were the type of mathematics curriculum (OUR versus traditional) and school lunch status (free or reduced lunch versus no free or reduced lunch). The dependent variable for Hypotheses 1 through 4 was mathematics achievement measured by ACT Aspire Mathematics test scores. According to Leech, Barrett, and Morgan (2015), a factorial between-groups design was appropriate because each participant score was in only one group, there were two or more independent variables, and there was only one dependent variable. Each of the four hypotheses in this study used a 2 x 2 factorial ANOVA.

Sample

This study's sample included a stratified random sample of scores from seventh- and eighth-grade students at two rural schools in Central Arkansas and two rural schools in Southeast Arkansas. The populations of the two schools in Central Arkansas, one using OUR and one using Big Ideas Math, were similar in demographics. The OUR school had a student population that consisted of Caucasian (92%) and Hispanic (8%). The comparison school had a racial demographic of Caucasian (88%), Hispanic (8%), American Indian/Alaskan Native (2%), and Two or more (3%). Students' family-income level was determined by school lunch status, with 37% of the OUR school's population receiving free or reduced lunches and 34% of the comparison school's students receiving free or reduced-cost lunches. The two schools were also similar in school demographics regarding grade configuration (seventh grade included in elementary and eighth grade included in high school), district size (OUR = 764 and comparison = 842), and the average teacher tenure at the present school (OUR = 12.56 years and comparison = 11.78 years). The schools were different in the student-teacher ratio (OUR = 5:1 and comparison = 8:1).

The two Southeast Arkansas schools from which samples of student data were drawn for this study had similar racial makeup and percentages of students with free or reduced lunch status but different building configurations and district sizes. The control group school used OUR, and the comparison school used the Engage NY mathematics curriculum. The OUR school had a student population that consisted of Caucasian (78%), African American (14%), Hispanic (5%), and Two or more (2%). The comparison school had Caucasian (83%), African American (10%), Hispanic (5%), and Two or more (2%). Socioeconomic status was determined by lunch status, with 62% of the OUR school's population on free or reduced lunches and 61% of the comparison school's students. Other demographics for the two schools included grade configuration (a sixth-grade through seventh-grade middle school building for the OUR school and a 7th-grade through and 12th-grade high school building for the comparison school), district size (OUR = 1,219 and comparison = 634), the average teacher tenure (OUR = 12.1 years and comparison = 8.2 years), and student-teacher ratio (OUR = 11:1 and comparison = 7:1).

This study's sample data were obtained using a stratified random sample of scores from the four schools in the study. Each grade level data was stratified by family-income level and gender, yielding a sample that consisted of 160 seventh graders and 160 eighth graders. For each grade level, the sample included 40 male, low family-income level, OUR use; 40 female, low family-income level, OUR use; 40 male, not low family-income level, OUR use; 40 female, not low family-income level, OUR use; 40 male, low family-income level, traditional curriculum use; 40 female, low family-income level, traditional curriculum use; 40 male, not low family-income level, traditional curriculum use; and 40 female, not low family-income level, traditional curriculum use. The ethnicity of students in the sample included Caucasian (88.1%), African American (6.9%), Two or more races (4.1%), and three students missing ethnicity data (0.9%).

Instrumentation

Scores from the mathematics subtest of the 2019 ACT Aspire Summative Assessment served as the instrument used to measure student achievement in this study. The ACT Aspire mathematics subtest scores were obtained in the form of secondary data from school databases. The ACT Aspire mathematics subtest scale score was used to provide data for the dependent variables in Hypothesis 1-4. The mathematics scale score ranges from 400-453 in seventh grade and 400-456 in eighth grade, with 400 being a low score (ACT, 2019). According to ACT (2019), the ACT Aspire test used items across an expected learning trajectory for each domain, and expected grade-level student achievement across the trajectory is considered.

Students in grades 3-10 in Arkansas schools take the ACT Aspire Summative Assessment to measure achievement each year. ACT (2019) noted that the mathematics test measures topics including the number system, expressions and equations, ratios and proportional reasoning (Grade 7), functions (Grade 8), geometry, and statistics and probability. The test also measures lasting content, a content category created to assess students' knowledge of mathematical content expected to be retained from previous grade levels (numbers and operation in base 10, numbers and operations-fractions, operations and algebraic thinking, and measurement and data). Item types on the subtest included selected-response, constructed-response, and technology-enhanced. Each correct selected-response and the technology-enhanced item has a score of 1 point with no points deducted for incorrect responses. Trained raters score constructed-response items according to a predetermined rubric. The ACT Aspire also meets reliability benchmarks. According to ACT (2019), Cronbach's alpha was used to determine an internal reliability coefficient range for the mathematics subtest in each grade: seventh grade (.86-.87) and eighth grade (.87-.88), as shown in Table 1.

Table 1

Reliability of ACT Aspire Mathematics Subtest

Grade Level	α	Standard Error of Measurement/ Scale Score	Scale Score Ranges
7	.86-.87	2.74	400-453
8	.87-.88	2.82	400-456

Several validity measures were investigated during the ACT Aspire development, and validity measures are employed with each new form of the assessment. According to ACT (2019), the validity of the ACT Aspire is obtained by determining that scores on the exam are indicative of performance on a particular set of constructs based on the ACT College and Career Readiness Standards (Grades 8 and above) and the ACT Readiness Standards (Grades 3-7). These standards were developed by content and measurement experts based on research conducted in the National ACT Curriculum Study (ACT, 2019). Item writers using these standards develop assessment items that undergo internal and external audits to ensure validity. Additionally, pretests are administered to ensure item quality and characteristics. The ACT Aspire passes validity for construct- and criterion-related measures (ACT, 2019).

Data Collection Procedures

After approval was obtained from the Institutional Review Board, the researcher contacted building administrators from participating schools to obtain permission to use students' anonymized scores and demographic data from the ACT 2019 mathematics subtest. In the spring of 2019, educators in all four schools administered the ACT Aspire mathematics subtest to all the students as part of the ACT Aspire Summative Assessment to measure achievement. Once the data were received, they were kept on password-protected devices to ensure privacy. Scores of students labeled “Migrant” were excluded from data collections since students of migrant parents were likely not in the school for a full school year. The researcher then entered demographic data and assessment results into an Excel spreadsheet, sorted the data based on gender and family-income level, and used the random number generator to obtain a stratified random sample of student scores for use in the study.

Analytical Methods

This study's data were analyzed using the *IBM Statistical Packages for the Social Sciences Version 26* (IBM Corporation, 2019). Each of the four hypotheses was analyzed with a 2 x 2 factorial ANOVA, and a two-tailed test with a .05 level of significance was used for statistical analysis. Data were examined to verify that the assumptions were met for the test of significance, and there were no outliers before running statistical tests (Leech et al., 2015). To test Hypotheses 1-2, two 2 x 2 ANOVAs (one for seventh-grade and one for eighth-grade students) were conducted using Curriculum Type (OUR versus traditional) by gender (male versus female) as the independent variables. Hypotheses 3-4 were tested by conducting two 2 x 2 ANOVAs (one for seventh-grade and one for eighth-grade students) using Curriculum Type (OUR versus traditional) by family-income level (free or reduced lunch versus no free or reduced lunch) as the independent variables. The dependent variable for Hypotheses 1-4 was mathematics achievement measured by scores on the 2019 ACT Aspire mathematics subtest.

Limitations

There are several limitations to the design of this study. First, the independent variables could not be manipulated. The researcher used a causal-comparative study because the independent variables of gender and family-income level could not be manipulated. Second, the fidelity of implementing the curriculum at each school was not evaluated or considered as part of this study. The type of curriculum used by each school was based upon reports by the school administration and a visit to the schools by either the researcher (3 schools) or another Arkansas State Mathematics Specialist (1 school). Although the visits confirmed the curriculum was in use at each school, no measure of the fidelity of use was included in this study.

Third, a potential threat to the validity of the instrument used in this study exists. Arkansas uses *Arkansas Mathematics Standards, Grades 6-8* (Arkansas Department of Education, 2016), but the ACT Aspire Summative assessment is based on ACT College and Career Readiness Standards (Grades 8 and above) and the ACT Readiness Standards

(Grades 3-7). Since the ACT Aspire summative assessment was deemed by state officials to be the educational measure for students' mathematics achievement in Arkansas (Arkansas Department of Education, 2014), the assumption of the correlation between the standards was assumed by the researcher. No document verifying this correlation could be located.

Fourth, the limited geographic area and the limited number of schools from which the study samples were taken may result in limited applicability of the results. Scores from the sample represented only four schools, only rural schools, only schools in Central and Southeast Arkansas, and schools with limited ethnic diversity. This limitation could not be avoided due to the limited number of schools implementing OUR at the time that were willing to allow student scores to be used in the study. Finally, since the sample included scores from only four schools, only two examples of traditional mathematics curricula were represented in this study. Other traditional curricula not used by schools in this study may have different effects on student achievement.

Summary

This study consisted of four hypotheses, each tested using a 2 x 2 factorial ANOVA. The dependent variable for each hypothesis was mathematics achievement scores (2019 ACT Aspire mathematics subtest scores of seventh-grade students for Hypothesis 1 and 3; eighth-grade students for Hypothesis 2 and 4). The independent variables for Hypothesis 1and 2 were the type of mathematics curriculum used (OUR versus traditional) and gender (male versus female). The independent variables for Hypothesis 3 and 4 were the type of mathematics curriculum used (OUR versus traditional) and family-income level (No free or reduced lunch versus free or reduced lunch). A stratified random sample of student achievement scores from two rural Central Arkansas and two rural Southeast Arkansas were used in the analysis. Chapter 4 contains a discussion of the results of the data analysis.

CHAPTER IV

RESULTS

The purposes of this study were four-fold. First, the purpose of this study is to determine the effects by gender of the mathematics curriculum used (OUR versus traditional) on mathematics achievement scores (2019 ACT Aspire mathematics subtest) of seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Second, the purpose of this study is to determine the effects by gender of mathematics curriculum used (OUR versus traditional) on mathematics achievement scores of seventh- and eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Hypothesis 1-2 were tested using two 2 x 2 factorial ANOVAs (one for each grade). The independent variables for Hypothesis 1-2 were the mathematics curriculum used (OUR versus traditional) and gender (male versus female), and the dependent variable was mathematics achievement (2019 ACT Aspire mathematics subtest). Third, the purpose of this study is to determine the effects by family-income level on mathematics achievement scores of seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Fourth, the purpose of this study is to determine the effects by family-income level (as measured by school lunch status) on mathematics achievement scores (2019 ACT Aspire mathematics subtest) of eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Hypothesis 2-3 were tested using two 2 x 2 factorial ANOVAs (one for each grade). The independent variables for Hypothesis 3-4 were the mathematics curriculum used (OUR versus traditional) and family-income level (No free or reduced lunch versus Free or reduced lunch), and the dependent variable was mathematics achievement (2019 ACT Aspire mathematics subtest).

Hypothesis 1

Hypothesis 1 stated that no significant difference will exist by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics subtest for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Two additional hypotheses were also examined as part of this analysis: (1) Curriculum type does not significantly affect mathematics achievement, and (2) Gender does not significantly affect mathematics achievement. The assumptions of independent observations, homogeneity of variances, and normal distributions of the dependent variable for each group were checked. The study's design was such that the assumption of independent observations was met; no subject contributed scores in more than one group. Normality was tested with the Shapiro-Wilk test, and the assumption was met for all groups: male traditional curriculum, $W(40) = 0.98$, $p = .605$; female traditional curriculum, $W(40) = 0.97$, $p = .277$; male OUR curriculum, $W(40) = 0.97$, $p = .318$; and female OUR curriculum, $W(40) = 0.96$, $p = .147$. A Levene's test, $F(3, 156) = 4.83$, $p = .000$, indicated that homogeneity of variances was violated. However, according to Leech et al. (2015), since SPSS uses the regression approach to calculate ANOVA, the test can be conducted, but this violation should be considered when deciding on a post hoc test. The means and standard deviations of each group are recorded in Table 2.

Table 2

Descriptive Statistics for Seventh-Grade Students' Mathematics Achievement by Type of Curriculum and Gender

Gender	Mathematics Curriculum	*M*	*SD*	*N*
Male	Traditional	419.10	5.52	40
	OUR	420.80	9.14	40
	Total	419.95	7.55	80
Female	Traditional	421.30	5.46	40
	OUR	423.20	7.00	40
	Total	422.25	6.31	80
Total	Traditional	420.20	5.57	80
	OUR	422.00	8.18	80
	Total	421.10	7.03	160

To test Hypothesis 1, a 2 x 2 factorial ANOVA was conducted to evaluate the effects of the type of mathematics curriculum used by gender on mathematics achievement as measured by the 2019 ACT Aspire mathematics subtest. Figure 3 shows the means for mathematics achievement as a function of curriculum type and gender.

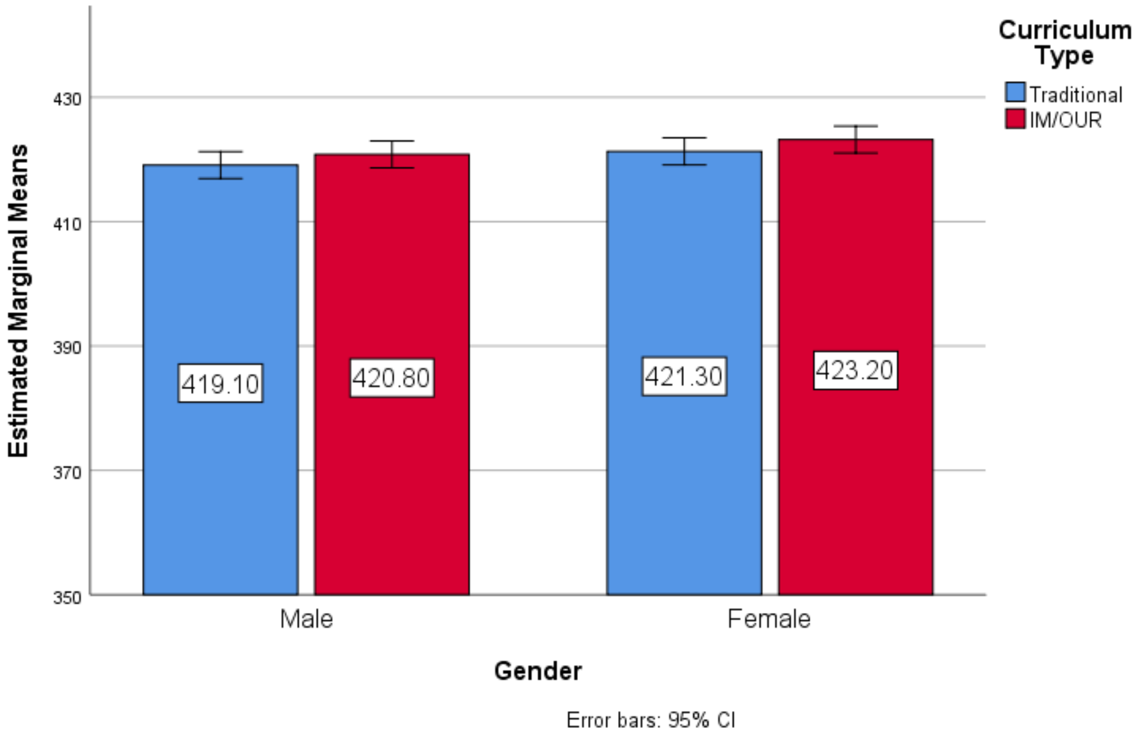

Figure 3. Mean mathematics achievement of seventh-grade students by curriculum type and gender.

The analysis revealed no significant interaction, $F(1, 156) = 0.01$, $p = .928$, partial $\eta^2 < 0.001$, between curriculum type and gender, and as a result, the null hypothesis could not be rejected. Table 3 contains the results of the analysis.

Table 3

Factorial ANOVA Results for Seventh-Grade Students' Mathematics Achievement as a Function of Curriculum Type and Gender

Source	*SS*	*df*	*MS*	*F*	*p*	*ES*
Curriculum Type	129.60	1	129.60	2.69	.103	0.017
Gender	211.60	1	211.60	4.39	.038	0.027
Curr Type*Gender	0.40	1	0.40	0.01	.928	0.000
Error	7518.80	156	48.20			
Total	28379894.00	160				

Note. Curr Type*Gender = Curriculum Type by Gender.

Given that the interaction was not significant, the main effects for each independent variable were examined separately. The main effect for curriculum type was not significant, $F(1, 156) = 2.69$, $p = .103$, partial $\eta^2 = 0.017$, and this null hypothesis was not rejected. The mean of the OUR group ($M = 422.00$, $SD = 8.18$) was higher but not significantly different from the mean of the traditional group ($M = 420.20$, $SD = 5.57$). This result indicated that curriculum type, regardless of gender, was not a significant factor for increasing students' mathematics achievement. On the other hand, the main effect for gender was significant, $F(1, 156) = 4.39$, $p = .038$, partial $\eta^2 = 0.027$, and the null hypothesis, that gender does not significantly affect mathematics achievement, was rejected. The mean of the female group ($M = 422.25$, $SD = 6.31$) was significantly higher compared to the mean of the male group ($M = 419.95$, $SD = 7.55$). This result indicated that gender, regardless of curriculum type, was a significant factor for increasing students' mathematics achievement. However, gender predicted only approximately 2.7% of the variance for mathematics achievement, which is considered a small effect (Cohen, 1988). Therefore, a significant difference in the mathematics achievement of seventh-grade male and female students did exist.

Hypothesis 2

Hypothesis 2 stated that no significant difference will exist by gender between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics subtest for eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Two additional hypotheses were also examined as part of this analysis: (1) Curriculum type does not significantly affect mathematics achievement, and (2) Gender does not significantly affect mathematics achievement. The assumptions of independent observations, homogeneity of variances, and normal distributions of the dependent variable for each group were checked. The study's design was such that the assumption of independent observations was met; no subject contributed scores in more than one group. Normality was tested with the Shapiro-Wilk test, and the assumption was met for all groups except for the female traditional curriculum group: male, traditional curriculum, $W(40) = 0.95$, $p = .061$; female, traditional curriculum, $W(40) = 0.93$, $p = .014$; male, OUR curriculum, $W(40) = 0.98$, $p = .586$; and female, OUR curriculum, $W(40) = 0.97$, $p = .356$. However, according to Leech et al. (2015), factorial ANOVA is robust against assumptions of normality of the dependent variable and recommends considering the transformation of data only if skewness is more than 1.0 or less than -1.0. The skewness values of the groups were male, traditional curriculum (.618); female, traditional curriculum (.970); male, OUR curriculum (.004); and female, OUR curriculum (.085). Since the skewness was not severe and was in the same direction for each group, the ANOVA was conducted. A Levene's test, $F(3, 156) = 1.75$, $p = .158$, indicated that homogeneity of variances was not violated. The means and standard deviations of each group are recorded in Table 4.

Table 4

Descriptive Statistics for Eighth-Grade Students' Mathematics Achievement by Type of Curriculum and Gender

Gender	Mathematics Curriculum	*M*	*SD*	*N*
Male	Traditional	422.73	7.86	40
	OUR	426.45	8.50	40
	Total	424.69	8.35	80
Female	Traditional	424.40	6.06	40
	OUR	427.40	8.35	40
	Total	425.90	7.42	80
Total	Traditional	423.56	7.03	80
	OUR	426.93	8.39	80
	Total	425.24	7.90	160

To test Hypothesis 2, a 2 x 2 factorial ANOVA was conducted to evaluate the effects of the type of mathematics curriculum used by gender on mathematics achievement as measured by the 2019 ACT Aspire mathematics subtest. Figure 4 shows the means for mathematics achievement as a function of curriculum type and gender.

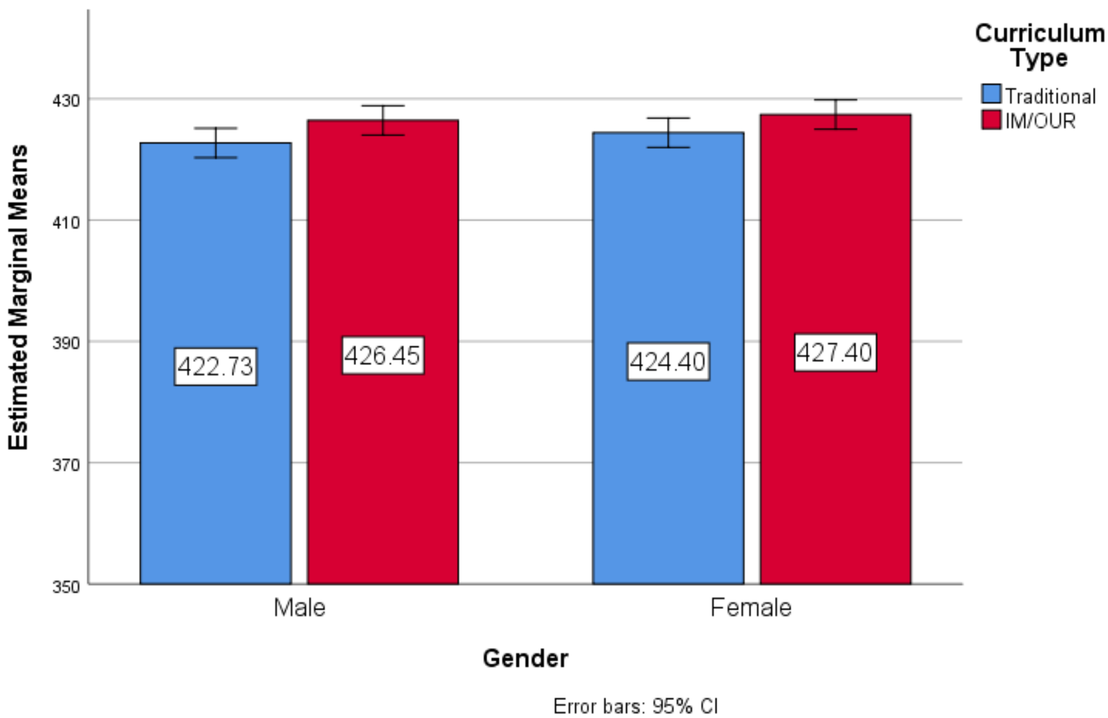

Figure 4. Mean mathematics achievement of eighth-grade students by curriculum type and gender.

The analysis revealed no significant interaction $F(1, 156) = 0.09$, $p = .768$, partial $\eta^2 = 0.001$ between curriculum type and gender, and as a result, the null hypothesis could not be rejected. Table 5 contains the results of the analysis.

Table 5

Factorial ANOVA Results for Eighth-Grade Students' Mathematics Achievement as a Function of Curriculum Type and Gender

Source	*SS*	*df*	*MS*	*F*	*p*	*ES*
Curriculum Type	452.26	1	452.26	7.51	.007	0.046
Gender	68.91	1	68.91	1.15	.286	0.007
Curr Type*Gender	5.26	1	5.26	0.09	.768	0.001
Error	9391.08	156	60.20			
Total	28943077.00	160				

Note. Curr Type*Gender = Curriculum Type by Gender.

Given that the interaction was not significant, the main effects for each independent variable were examined separately. The main effect for the type of mathematics curriculum was significant, $F(1, 156) = 7.51$, $p = .007$, partial $\eta^2 = 0.046$, and the null hypothesis, that curriculum type does not significantly affect mathematics achievement, was rejected. The mean of the OUR group ($M = 426.93$, $SD = 8.39$) was significantly higher compared to the mean of the traditional group ($M = 423.56$, $SD = 7.03$). This result indicated that curriculum type, regardless of gender, was a significant factor for increasing students' mathematics achievement. The curriculum type predicted approximately 4.6% of the variance for mathematics achievement, which is considered a small effect size. However, the main effect for gender was not significant, $F(1, 156) = 1.15$, $p = .286$, partial $\eta^2 = 0.007$, and the null hypothesis was not rejected. The mean of the female group (*M* = 425.90, *SD* = 7.42) was higher but not significantly different from the mean of the male group (*M* = 424.69, *SD* = 8.35). This result indicated that gender, regardless of curriculum type, was not a significant factor for increasing students' mathematics achievement. Therefore, a significant difference in the mathematics achievement of eighth-grade students using OUR mathematics curriculum and those using traditional curriculum did exist.

Hypothesis 3

Hypothesis 3 stated that no significant difference will exist by family-income level (school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics subtest for seventh-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Two additional hypotheses were also examined as part of this analysis: (1) Curriculum type does not significantly affect mathematics achievement, and (2) Family-income level does not significantly affect mathematics achievement. The assumptions of independent observations, homogeneity of variances, and normal distributions of the dependent variable for each group were checked. The study's design was such that the assumption of independent observations was met; no subject contributed scores in more than one group. Normality was tested with the Shapiro-Wilk test, and the assumption was met for all groups: traditional curriculum no free or reduced lunch, $W(40) = 0.98$, $p = .680$; traditional curriculum free or reduced lunch, $W(40) = 0.97$, $p = .388$; OUR curriculum no free or reduced lunch, $W(40) = 0.97$, $p = .406$; and OUR curriculum free or reduced lunch, $W(40) = 0.98$, $p = .698$. A Levene's test, $F(3, 156) = 9.21$, $p = .000$, indicated that homogeneity of variances was violated. However, according to Leech et al. (2015), since SPSS uses the regression approach to calculate ANOVA, the test can be conducted, but this violation should be considered when deciding on a post hoc test. The means and standard deviations of each group are recorded in Table 6.

Table 6

Descriptive Statistics for Seventh-Grade Students' Mathematics Achievement by Curriculum Type and Family Income

Lunch Participation	Mathematics Curriculum	*M*	*SD*	*N*
No Free/Reduced	Traditional	421.45	6.26	40
	OUR	423.78	9.37	40
	Total	422.61	8.00	80
Free/Reduced	Traditional	418.95	4.53	40
	OUR	420.23	6.42	40
	Total	419.59	5.56	80
Total	Traditional	420.20	5.57	80
	OUR	422.00	8.18	80
	Total	421.10	7.03	160

To test Hypothesis 3, a 2 x 2 factorial ANOVA was conducted to evaluate the effects of the type of mathematics curriculum used by family-income level (school lunch status) on mathematics achievement as measured by the 2019 ACT Aspire mathematics subtest. Figure 5 shows the means for mathematics achievement as a function of curriculum type and family-income level.

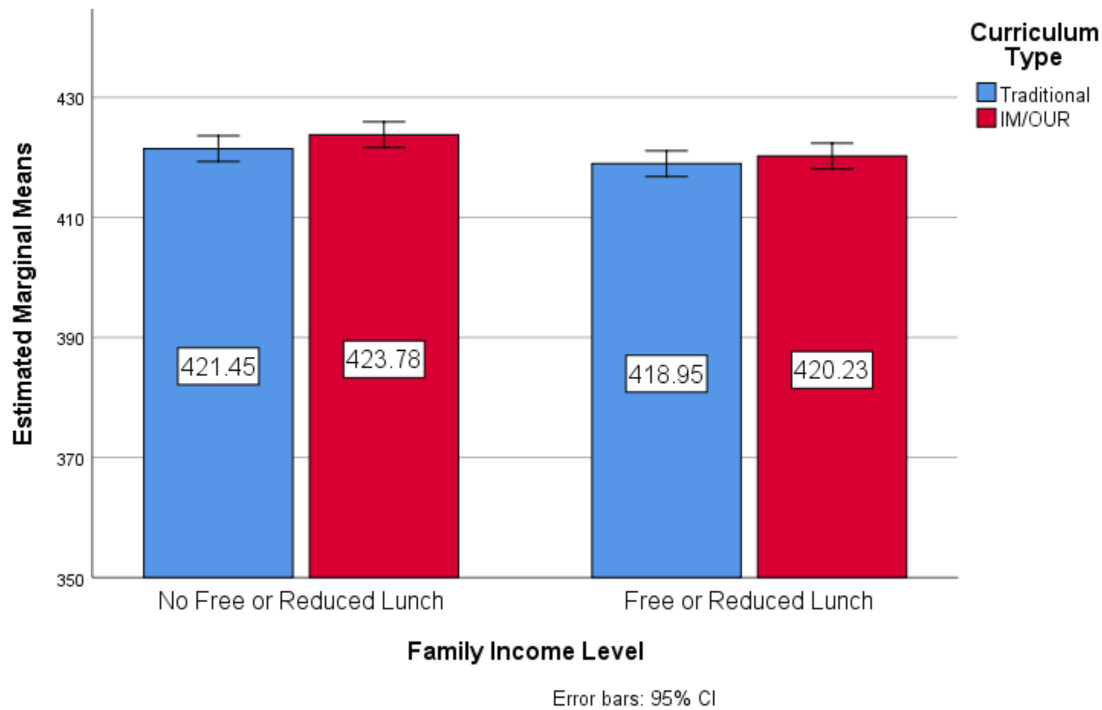

Figure 5. Mean mathematics achievement of seventh-grade students by curriculum type and family-income level.

The analysis revealed no significant interaction, $F(1, 156) = 0.23$, $p = .629$, partial $\eta^2 = 0.001$, between curriculum type and family-income level, and as a result, the null hypothesis could not be rejected. Table 7 contains the results of the analysis.

Table 7

Factorial ANOVA Results for Seventh-Grade Students' Mathematics Achievement as a Function of Curriculum Type and Family Income

Source	*SS*	*df*	*MS*	*F*	*p*	*ES*
Curriculum Type	129.60	1	129.60	2.75	.099	0.017
Family-Income Level	366.03	1	366.03	7.77	.006	0.047
Curr Type*Fam Inc	11.025	1	11.03	0.23	.629	0.001
Error	7353.75	156	4			
Total	28379894.00	160				

Note. Curr Type*Fam Inc = Curriculum Type by Family-Income Level.

Given that the interaction was not significant, the main effects for each independent variable were examined separately. The main effect for the type of mathematics curriculum was not significant, $F(1, 156) = 2.75$, $p = .099$, partial $\eta^2 = 0.017$, and the null hypothesis was not rejected. The mean of the OUR group ($M = 422.00$, $SD = 8.18$) was higher but not significantly different compared to the mean of the traditional group ($M = 420.20$, $SD = 5.57$). This result indicated that curriculum type, regardless of gender, was not a significant factor for increasing students' mathematics achievement. The main effect for family-income level was significant, $F(1, 156) = 7.77$, $p = .006$, partial $\eta^2 = 0.047$, and the null hypothesis, that family-income level does not significantly affect mathematics achievement, was rejected. The mean of the no free or reduced lunch group ($M = 422.61$, $SD = 8.00$) was significantly higher compared to the mean of the free or reduced lunch group (*M* = 419.59, *SD* = 5.56). This result indicated that lunch eligibility, regardless of curriculum type, was a significant factor for increasing students' mathematics achievement. However, family-income level predicted only approximately 4.7% of mathematics achievement variance, which was considered a small effect size. Therefore, a significant difference in the mathematics achievement of students with low and high family-income levels did exist.

Hypothesis 4

Hypothesis 4 stated that no significant difference will exist by family-income level (school lunch status) between students using OUR curriculum versus students using traditional curriculum on mathematics achievement as measured by the ACT Aspire mathematics subtest for eighth-grade students in two Central Arkansas schools and two Southeast Arkansas schools. Two additional hypotheses were also examined as part of this analysis: (1) Curriculum type does not significantly affect mathematics achievement, and (2) Family-income level does not significantly affect mathematics achievement. The assumptions of independent observations, homogeneity of variances, and normal distributions of the dependent variable for each group were checked. The study's design was such that the assumption of independent observations was met; no subject contributed scores in more than one group. Normality was tested with the Shapiro-Wilk test, and the assumption was met for all groups except the female traditional curriculum group: male traditional curriculum, $W(40) = 0.96$, $p = .170$; female traditional curriculum, $W(40) = 0.92$, $p = .007$; male OUR curriculum, $W(40) = 0.98$, $p = .646$; and female OUR curriculum, $W(40) = 0.96$, $p = .189$. However, according to Leech et al. (2015), factorial ANOVA is robust against assumptions of normality of the dependent variable and recommends transformation of data only if skewness is more than 1.0 or less than -1.0. The skewness values of the groups were no free or reduced lunch traditional curriculum (.359); free or reduced lunch traditional curriculum (.982); no free or reduced lunch OUR curriculum (-.007); and no free or reduced lunch OUR curriculum (-.022). Since the skewness was not severe, the ANOVA was conducted. A Levene's test, $F(3, 156) = 1.51$, $p = .215$, indicates that homogeneity of variances was not violated. The means and standard deviations of each group are recorded in Table 8.

Table 8

Descriptive Statistics for Eighth-Grade Students' Mathematics Achievement by Type of Curriculum and Family Income

Lunch Participation	Mathematics Curriculum	*M*	*SD*	*N*
No Free/Reduced	Traditional	424.85	6.95	40
	OUR	428.35	8.74	40
	Total	426.60	8.04	80
Free/Reduced	Traditional	422.28	6.95	40
	OUR	425.50	7.88	40
	Total	423.89	7.56	80
Total	Traditional	423.56	7.03	80
	OUR	426.93	8.39	80
	Total	425.24	7.90	160

To test Hypothesis 4, a 2 x 2 factorial ANOVA was conducted to evaluate the effects of the type of mathematics curriculum used by family-income level (school lunch status) on mathematics achievement as measured by the 2019 ACT Aspire mathematics subtest. Figure 6 shows the means for mathematics achievement as a function of curriculum type and family-income level.

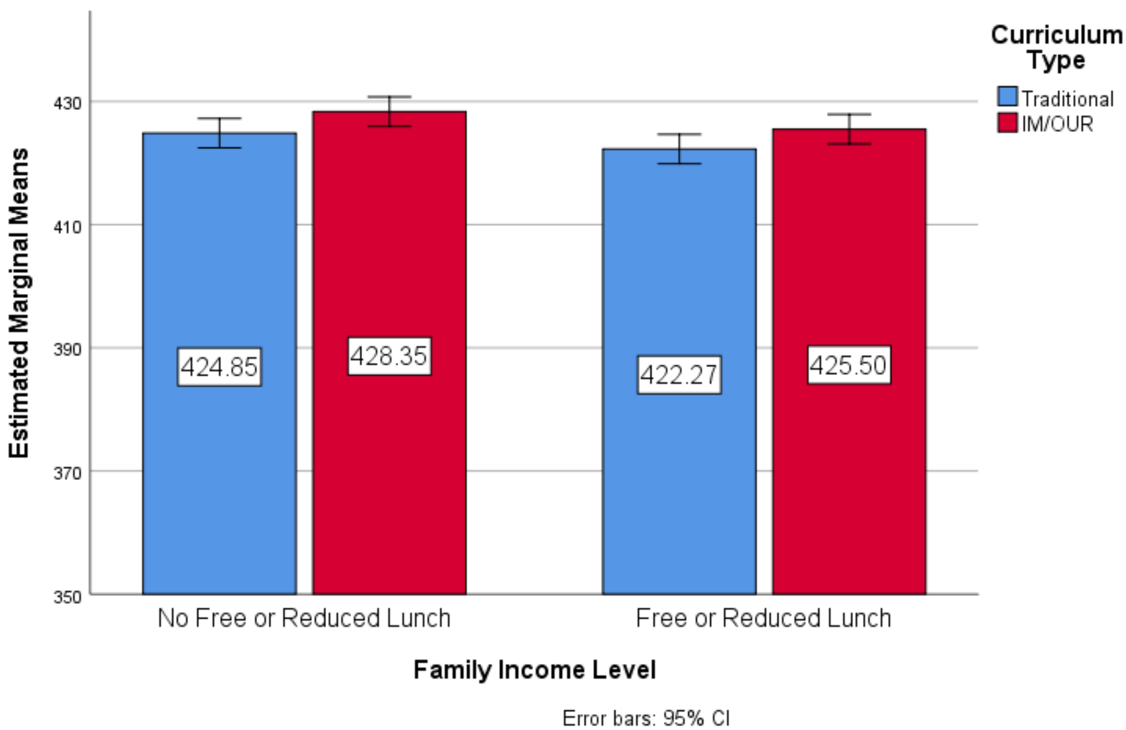

Figure 6. Mean mathematics achievement of eighth-grade students by curriculum type and family-income level.

The analysis revealed no significant interaction, $F(1, 156) = 0.01$, $p = .910$, partial $\eta^2 < 0.001$, between curriculum type and family-income level, and as a result, the null hypothesis could not be rejected. Table 9 contains the results of the analysis.

Table 9

Factorial ANOVA Results for Eighth-Grade Students' Mathematics Achievement as a Function of Curriculum Type and Family Income

Source	*SS*	*df*	*MS*	*F*	*p*	*ES*
Curriculum Type	452.26	1	452.26	7.69	.006	0.047
Family Income-Level	294.31	1	294.31	5.01	.027	0.031
Curr Type*Fam Inc	0.76	1	0.76	0.01	.910	0.000
Error	9170.18	156	58.78			
Total	28943077.00	160				

Note. Curr Type*Fam Inc = Curriculum Type by Family-Income Level.

Given that the interaction was not significant, the main effects for each independent variable was examined separately. The main effect for the type of mathematics curriculum was significant, $F(1, 156) = 7.69$, $p = .006$, partial $\eta^2 = 0.047$, and the null hypothesis that the type of mathematics curriculum does not significantly affect mathematics achievement was rejected. The mean of the OUR group ($M = 426.93$, $SD = 8.39$) was significantly higher compared to the mean of the traditional group ($M = 423.56$, $SD = 7.03$). This result indicated that curriculum type, regardless of lunch eligibility, was a significant factor for increasing students' mathematics achievement. However, curriculum type predicted only approximately 4.6% of mathematics achievement variance, which is considered a small effect size. Similarly, the main effect for family-income level was significant, $F(1, 156) = 5.01$, $p = .027$, partial $\eta^2 = 0.031$, and the null hypothesis, that family-income level does not significantly affect mathematics achievement, was rejected. The mean of the no free or reduced lunch group (M = 426.60, SD = 8.04) was significantly higher compared to the mean of the free or reduced lunch group (M = 423.89, SD = 7.56). This result indicated that lunch eligibility, regardless of curriculum type, was a significant factor for increasing students' mathematics achievement. However, family-income level predicted only approximately 3.1% of mathematics achievement variance, which is considered a small effect size. Evidence indicates a significant difference in the mathematics achievement of eighth-grade students with curriculum type and a significant difference in students' mathematics achievement with lunch eligibility.

Summary

This study consisted of four hypotheses, each tested using a 2 x 2 factorial ANOVA. The dependent variable for each hypothesis was student mathematics achievement as measured by the 2019 ACT Aspire mathematics subtest scores (seventh-grade scores for Hypothesis 1 and 3; eighth-grade scores for Hypothesis 2 and 4). The independent variables for Hypothesis 1and 2 were the type of mathematics curriculum used (OUR versus traditional) and gender (male versus female). The independent variables for Hypothesis 3 and 4 were the type of mathematics curriculum used (OUR versus traditional) and family-income level (no free or reduced lunch versus free or reduced lunch). A summary of the data analysis results for the four hypotheses is presented in Table 10.

Table 10

Summary of Statistically Significant Results for Hypothesis 1 Through 4

Hypothesis	Grade	Significant Result	*p*	*ES*
1	7	Main effect of Gender	.038	0.027
2	8	Main effect of Curriculum Type	.007	0.046
3	7	Main effect of Family-Income Level	.006	0.047
4	8	Main effect of Curriculum Type	.006	0.047
4	8	Main effect of Family-Income Level	.027	0.031

Results of tests in this study indicated that seventh-grade females have higher mathematics achievement than males and that seventh-grade students from families with higher income levels have higher mathematics achievement than students from families with low family-income levels. Results also indicated that eighth-grade students using the OUR mathematics curriculum have higher mathematics achievement than those using a traditional mathematics curriculum and that eighth-grade students from families with higher income levels have higher mathematics achievement than students from families with low family-income levels in these Central and Southeast Arkansas schools. Chapter V will include findings and implications, the potential for practice or policy, and future research considerations based upon this study's results.

CHAPTER V

DISCUSSION

This study was conducted to determine the effects of the type of mathematics curriculum used on the mathematics achievement scores of seventh- and eighth-grade students by gender and family-income level. This chapter presents a summary of the main findings of this study. The implications of the relationship between the types of mathematics curriculum, gender, and family-income level are discussed. Finally, recommendations for practice related to mathematics curriculum use and future research considerations are provided.

Findings and Implications

Overall, in this study, no meaningful interaction between type of curriculum and gender, or type of curriculum and family income, was found on the mathematics achievement of seventh-grade and eighth-grade students. However, the results highlighted several independent effects of type of curriculum, gender, and family income on students' mathematics achievement at the grade levels under investigation.

Findings by Hypothesis

For Hypothesis 1, the findings indicated that the use of the OUR mathematics curriculum did not affect seventh-grade students' mathematics achievement. The findings also revealed that seventh-grade females had significantly higher levels of mathematics achievement than seventh-grade males. For Hypothesis 2, the use of the OUR mathematics curriculum was connected to significantly higher mathematics achievement for eighth-grade students when compared to the use of traditional mathematics curricula. On the other hand, no meaningful differences in eighth-grade students' mathematics achievement were found based on their gender. For Hypothesis 3, the findings indicated that the use of the OUR mathematics curriculum did not affect seventh-grade students' mathematics achievement. However, the findings revealed that seventh-grade students receiving free or reduced lunch had significantly lower mathematics achievement scores than those who did not receive free or reduced lunch. For Hypothesis 4, not only was the use of the OUR mathematics curriculum associated with significantly higher mathematics achievement, but the eighth-grade students who did not participate in the free or reduced lunch program had higher mathematics achievement than students who participated in the program.

Implications Related to the Use of Mathematics Curriculum

The findings in this study provide evidence that constructivist-teaching methods, such as PBL, that actively involve students in the learning process lead to higher student achievement than traditional methods for students in Grade 8. Piaget (1975) suggested that students construct logical structures as they act on problems and that these logical structures can be used to solve new problems (see Figure 1). In this study, the benefits of the constructivist approach to learning revealed a greater impact on students' academic achievement in Grade 8, more so than for the students in Grade 7. There is room to speculate on why a positive effect of using OUR PBL curriculum is observed at one grade level but not the other. Differences in the complexity of the mathematics content, students' experience with the PBL approach, and the teachers' fidelity in implementing

OUR curriculum are among possible other factors. Despite these unknowns, the overwhelming evidence from this study suggests that high school students benefit from the implementation of constructivist PBL curricula such as OUR. Rosli et al. (2014), in a meta-analysis of problem- and project-based learning, and Yancy (2012), found that the use of PBL resulted in positive gains in student achievement scores. This study's results align well with the existing evidence indicating PBL use positively affects student achievement in mathematics. This evidence reinforces the basic tenets of the constructivist theory that connecting abstract content to real-world ideas that learners can identify with is an effective way to facilitate the delivery of mathematics content to high school students.

Beyond the direct benefits to their academic achievement, the implementation of PBL may have other positive effects on students. Albanese and Mitchell (1993) and Vernon and Blake (1993) asserted that those experiencing PBL place greater emphasis on understanding content. This understanding of students may overcome the disadvantage of the time needed for PBL implementation noted by Albanese and Mitchell (1993). PBL use may also include other positive results for students such as better transfer of learning to new contexts (Budak, 2015; Ridgeway et al., 2003), positive student attitudes towards mathematics (Ridlon, 2009; Saragih & Napitupulu, 2015), and greater interest in understanding content (Albanese & Mitchell, 1993; Vernon & Blake, 1993). Considering all of this evidence, one can conclude that PBL use is as effective as or more effective than traditional teaching methods.

Additionally, this study's results indicated that the use of problem-based curricula is as or more effective than the use of traditional mathematics curricula. Cai et al. (2011), Mathematica Policy Research & What Works Clearinghouse (2017), and Ridgeway et al. (2003) reported that students in Grades 6-8 using the problem-based, Connected Mathematics Project curriculum had similar achievement to students using more traditional mathematics curriculum. Similarly, Ridlon (2009) found no mathematics achievement difference in Grades 6-8 students using the QUASAR Project Mathematics curriculum compared to those using more traditional mathematics curricula. Tarr et al. (2008) found no difference in grades 6-8 mathematics achievement of students in 24 schools using four different problem-based curriculum types funded by the National Science Foundation compared to students in 24 schools using different traditional mathematics curricula. Based on the results of this study, educators should consider using problem-based mathematics curricula at the eighth-grade level and possibly at the seventh-grade level because the use of problem-based mathematics curricula does not harm the mathematics achievement of seventh graders but is associated with higher mathematics achievement at the eighth-grade level.

Implications Related to Gender

The findings in this study related to the effect of gender on seventh- and eighth-grade students' mathematics achievement are limited. The lack of interaction between curriculum type and gender in this study suggested that PBL may not be effective for closing achievement gaps by gender, as suggested by Boaler and Staples (2008). However, gender difference that favored female students, regardless of curriculum type, was found at the seventh-grade level but not at the eighth-grade level. The lack of a difference by gender in the scores of eighth-grade students aligns with claims by Reilly et al. (2015), Moore (2015), and Witonski (2013) that the mathematics achievement gap between male and female students is closing. According to Else-Quest et al. (2010), analyses of international mathematics achievement scores indicated that achievement gaps were not present in all countries and that in some countries, an achievement gap favoring females existed. Mathematics achievement by gender varies in different countries, and as indicated by the achievement gap favoring seventh-grade females in this study, it could vary by region in the United States or by subgroups of the student population.

Implications Related to Family-Income Level

A key finding in this study is that mathematics achievement gaps still exist by family-income level at both the seventh-grade and eighth-grade levels. Therefore, educators should monitor achievement by family-income level and take steps to close any noted achievement gaps. Students receiving free or reduced lunch have lower mathematics achievement scores than students who do not receive free or reduced lunch. These findings are independent of the use of OUR or a more traditional mathematics curriculum. This study's findings contrasted the findings of Ridlon (2009) that the implementation of PBL resulted in increased student achievement of students from low family income backgrounds. However, the findings aligned more closely with those of Hwang et al. (2018), claiming that the achievement of students from low family income backgrounds may remain the same with PBL implementation.

Furthermore, evidence from this study supported Reardon’s (2013) assertions that students from low-income households scored lower on achievement tests than students from homes with higher family-income levels. Additionally, this study provided evidence to strengthen the claims of Alordiah et al. (2015), Boaler et al. (2011), Gustafsson et al.

(2018), and Pomeroy (2016) that students from families with lower income levels have lower mathematics achievement than students from families with higher income levels. Ultimately, this study adds to the knowledge regarding the academic challenges facing students from low income.

Recommendations

Potential for Practice/Policy

Interpretation of these results may lead to several recommendations useful to educators. First, since problem-based curricular materials appear to be as effective or more effective than traditional mathematics curricula, teachers, principals, and superintendents should implement PBL and consider using problem-based mathematics curricula such as OUR to assist educators. According to Boud and Feletti (1997), the translation of PBL to a new context without some changes is seldom possible, and mathematics curricula can help this process. From a constructivist viewpoint, as suggested by Vygotsky (2017), problems should fall within a student's zone of proximal development, and educators should facilitate rather than dispense learning. In line with this viewpoint, a problem-based curriculum provides teachers with well-written problems so that more time could be spent considering how to scaffold problems and facilitate learning so that the problem falls within the student’s zone of proximal development. According to Boud and Feletti (1997) and Margetson (1997), appropriate structures and critical reflection on the learning process are crucial during PBL implementation. Educators should be provided training and support in PBL implementation and the use of new curricular materials as they learn to implement constructivist teaching methods. The OUR (2019) mathematics curriculum is an open educational resource that is freely available to teachers, representing a low-cost (only indirect costs such as printing or internet access costs), high-quality option for mathematics curriculum that includes problems at different levels of student thinking. OUR is one possible choice of problem-based curricular materials. The implementation of PBL using problem-based curricula such as OUR and providing appropriate support for educators is recommended.

Second, based on the mixed results regarding the effect of gender on student achievement, educators should monitor student achievement by gender. This study's results did not suggest a cause for the noticed difference by gender among seventh-grade students but did indicate that the differences with certain groups seem to persist. If an achievement difference by gender exists in a school or subgroup within the school, a further examination into the causes of the problem and potential solutions may be advantageous. Implementation of measures based on data and research could help narrow or close any existing gaps in student achievement by gender and may also serve to help eliminate potential future achievement gaps.

Finally, since evidence indicates a difference in mathematics achievement by family-income level, educators should consider ways to narrow or close this achievement gap. Reardon (2013) suggested that children living in poverty may be affected by a lack of resources, an increased likelihood of being raised in a single-parent home, uneducated parents, and parents' anxiety. These challenges go beyond what happens in the school building; therefore, educators may need to partner with other organizations in the community to provide the support required for students from low family-income level backgrounds. Within the school, investigating and implementing research-based strategies for closing the achievement gap by family-income level could result in positive gains for all students, especially those from low family income backgrounds. For example, Dietrichson et al. (2017), after conducting a meta-analysis of 101 experimental or quasi-experimental studies, suggested that interventions such as tutoring, progress monitoring with feedback, and cooperative learning have a positive effect on the achievement of students from low socioeconomic backgrounds. Although the present study found no significant interaction between OUR use and different income levels on student achievement, others such as Boaler and Staples (2008) and Ridlon (2009) reported positive gains in students' achievement from low-income backgrounds with PBL implementation in mathematics. Mathematics achievement gaps by family-income level persist, and research-based strategies, such as tutoring, feedback, and cooperative learning, may help close the achievement gap. However, more research would be required to determine if and how PBL implementation may affect the mathematics achievement gap by family-income level.

Future Research Considerations

The findings in this study provide limited evidence of the effect of the use of PBL and problem-based curricula on the mathematics performance of seventh-grade and eighth-grade students. Therefore, further research is needed to gain a clearer knowledge of this phenomenon. In the extant literature, the use of PBL has been shown to affect attitudes, complex problem-solving abilities, choices of higher-level mathematics courses, and students' career choices. However, only a few studies examining these effects on students are available. Additionally, no evidence for the effects of problem-based mathematics curriculum use on these outcomes was found in the existing literature. Unfortunately, most studies examining the effects of using different types of mathematics curricula are non-experimental studies and do not focus on the long-term effects of the use of different curricula. Further investigation of the effects of the use of different mathematics curriculum types is warranted. The researcher, therefore, recommends the following considerations for further study.

First, an extension of this study measuring long-term effects of problem-based curriculum use, including measures of the fidelity of curriculum implementation, is recommended. Since Boaler and Staples' (2008) longitudinal study found that PBL implementation was effective for all students and specifically for those from low family-income level backgrounds, research extending the present study may provide evidence useful in determining the effectiveness of problem-based curricula in PBL implementation for all students and specific subgroups of students.

Second, an extension of this study that includes the effects of problem-based curricula use on other measures of student success, such as complex problem solving, student attitudes, students' choices to take higher-level mathematics, and students' choice of career would help determine if the use of current problem-based curricula affects any of these student characteristics.

Finally, more research, particularly experimental or quasi-experimental designs, is needed to directly compare the effects of the use of problem-based and traditional teaching curricula. While much research investigating traditional or problem-based teaching methods and curricula is available, very few studies could be located directly comparing the two methods. Of the studies that were located, few were of experimental or quasi-experimental design, limiting the generalizability of the evidence.

Conclusion

This study investigated the effects of the use of problem-based and traditional mathematics curriculum types by gender and family-income levels on the mathematics achievement of seventh- and eighth-grade students. The mathematics achievement of eighth-grade students using OUR, a problem-based mathematics curriculum, was significantly higher than for those using more traditional curriculum types. The mathematics achievement of seventh-grade students using the two mathematics curriculum types was similar. However, a difference was indicated by gender for seventh-grade students and by family-income level for both seventh- and eighth-grade students. Overall, this study's findings contribute to the evidence that mathematics achievement gaps by family-income level persist among high school students in the United States. Mathematics achievement gaps by gender and family-income level appear to be unaffected by curriculum type, so educators should monitor and investigate other strategies for closing these gaps. Finally, educational practices based on constructivist learning theory, specifically problem-based learning, appear to be effective for teaching mathematics at the middle school level, especially at the eighth-grade level.

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